On-farm water storage (OFWS) as tool to reduce risk

By

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A stochastic benefit-cost analysis is used to analyze the profitability of irrigating from an On-farm water storage (OFWS) system using a center pivot irrigation system (CPIS) compared to a rain-fed production system for corn and soybean in the Southeast while also incorporating risk in the form of stochastic prices, yields and weather. Findings indicate that producer's decision to invest in an OFWS is dependent on the existing rate of returns and risk aversion levels. When costs are paid up-front, net present values for irrigating from an OFWS are lower than that of rainfall when discount rates are just above 2%. Higher net present values for irrigation relative to rainfall production are realized when the cost of investment is financed rather than making an up-front payment at higher discount rates. Investing in an OFWS on small farm sizes is not a good option for risk averse producers but, under extreme risk aversion levels, decision makers may prefer to irrigate and insure their revenue at higher coverage levels than depend on rainfall. Cost assistance opportunities for crop producers to prevent downstream flow of nutrients from production fields through the use OFWS should be more than 40% to make irrigation more desirable than dryland production at 8% and 10% discount rates.

DEDICATION

This research is dedicated to my cousins Evana Agyeman Attafuah and Keona Agyeman Attafuah.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INRODUCTION

1.1 Background

With 70 percent of the world's annual consumption, agriculture is undoubtedly the largest consumer of the world's fresh water. Currently, irrigated agriculture accounts for 40 percent of global food production from 20 percent of cultivated land (FAO, 2016). Current predictions indicate an average annual increase of 0.6 percent in irrigated land between now and 2030 (UNESCO-WWAP, 2016). In 2005, O'Neill and Dobrowolski reported that farmers across the world are irrigating five times more acreage than they did at the beginning of the 20th century. This rise in irrigated agriculture may be related to the fact that yields and profit from irrigated fields are typically higher (UNESCO-WWAP, 2012; Evett, Carman, and Bucks, 2003) and less variable (Dowgert, 2010) compared to that of rain-fed agriculture.

Irrigated agriculture has emerged as a major contributor of U.S crop sales in the last several decades. In 2012, the United State Department of Agriculture (USDA) reported about 56 million acres of irrigated land in the U.S. The reported irrigated acreage covers 17 percent of U.S cropland, but contributes to half of all crop sales. The crops with the most land irrigated were corn for grain (13.3 million acres), soybeans for beans (7.4 million acres), and alfalfa (5.5 million acres) (USDA-NASS, 2012). Though irrigated agriculture is widely practiced across the U.S, reports on irrigated acres and crops indicates that some states depend more heavily on irrigation practices than others. Recent drought conditions in the Western United States have reduced the number of irrigated acres in the region significantly. Conversely, irrigated acres in the humid areas such as the southeast have increased, with notable expansion occurring in Mississippi, Louisiana, Arkansas and Georgia (USDA-NASS, 2012). With about 1.7 million acres of land under irrigation, Mississippi ranked 9th in the United States in irrigated area in 2012. Soybean and corn received the most irrigation with 863,200 and 425,872 acres irrigated respectively (USDA-NASS, 2012). Mississippi crop producers' dependence on supplemental irrigation to boost production has increased due to the increase in uncertainty of rainfall distributions, especially during low rainfall periods (Kebede et al. 2014).

The use of irrigation has over the years shown its advantages by reducing the potential losses that would have occurred due to uneven rainfall distribution. But, access to reliable sources of irrigation water, especially during dry seasons, remains a growing concern for Mississippi producers. This concern stems from the fact that groundwater has long been the main source of irrigation water in Mississippi, but the frequent withdrawal from this source has led to the significant reduction in water levels of several natural aquifers (Konikow, 2013). Approximately 98 percent of the water extraction from the Mississippi River Alluvial Aquifer (MRAA) is for agricultural activities (Arthur, 2001). The MRAA has seen its groundwater levels decrease substantially since the 1970's, with an annual rate of reduction of 100,000 to 300,000 acre-feet, primarily due to the increase in irrigated acres. Despite the prevailing situation, the growing demand for irrigation water continually leads to withdrawal from this source. The pressure on groundwater is evident in the increasing number of groundwater use permits in the state. Currently, there are over 18,500 (Figure 1.2) permits issued in the Delta alone (YMD, 2015).

Generally, the seasonal influx of plentiful rainfall received in the southeast renews natural aquifers. Unfortunately, the natural recharge of this resource is not sufficient to meet the growing demands from groundwater withdrawals (Ritshard, Cruise and Hatch, 1999). It is therefore important for producers in these areas to find alternative reliable sources of water for irrigated agriculture.

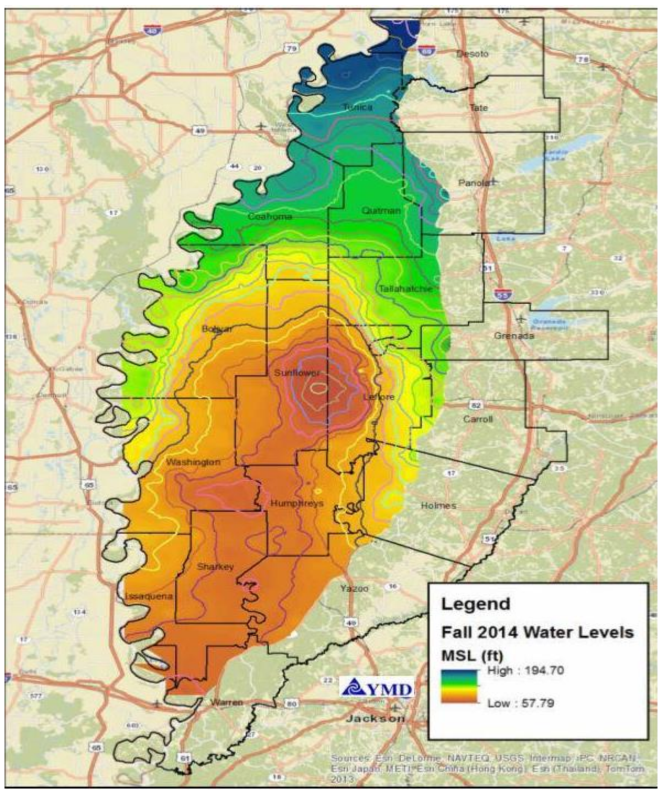

Figure 1.1 MRAA declining water levels

Source: YMD, (2015)

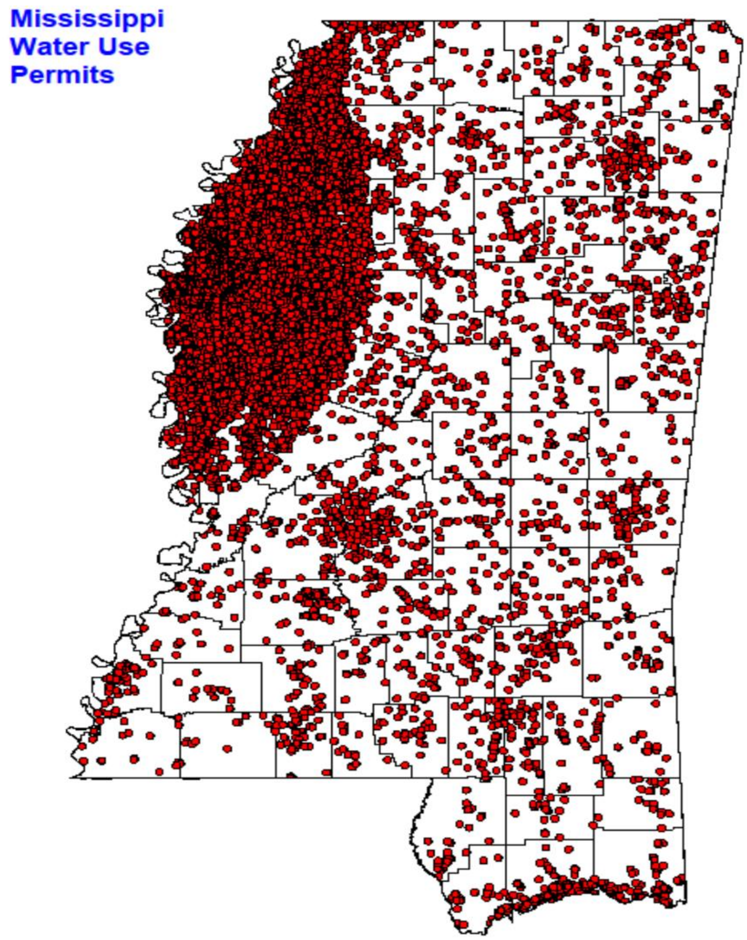

Figure 1.2 Groundwater use permits in Mississippi

Source YMD, (2015)

To supplement rainfall sufficiently with irrigation, crop producers and investors in Mississippi are gradually resorting to the use of on-farm water storage (OFWS) to capture and reuse runoff water for irrigation. OFWS is a best management practice (BMP) which involves capturing and holding of irrigation and rainfall runoff water onsite for later use. There are two common forms of OFWS (Figure 1.3). One of such system involves only a water storage pond or reservoir which directly receives runoff water from a field by gravity and is later redistributed onto the field for irrigation. The other involves a water storage pond and an additional drainage ditch commonly known as a tailwater recovery system (TWR). Tailwater recovery is defined as the re-use of excess water from the field that has not infiltrated into the soil (Stubb, 2016). TWR is usually constructed in areas where the contours of the land make it difficult to directly capture runoff water from the field into an irrigation reservoir. A TWR is therefore constructed to first capture the surface water before it is pumped into the irrigation reservoir and later re-distributed onto the field. OFWS has a great potential to be a reliable source of irrigation water for Mississippi crop producers and could save as much as 33,074,466 in^3/ha of groundwater annually if constructed with the appropriate dimensions (Ouyang et al. 2016).

The capture and reuse of surface water is an old practice in the field of agriculture but is relatively new in Mississippi. In Mississippi, the use of OFWS began to appear in 2010 when the National Resource Conservation Service (NRCS) recommended it as a BMP to help address the issue of hypoxia (depleted oxygen in water body) in the Mississippi river and Gulf of Mexico. Hypoxia is caused by excess nutrient and sediment loads from agricultural lands (Diaz, Rabalais and Breitburg, 2012; NOAA, 2009). Rainfall runoff from farm land in Mississippi contributes to about seventy percent of the nutrient loads that cause hypoxia (NOAA, 2009). Hypoxia and Eutrophication (increase in organic matter content in water) are primarily caused by an increase in nitrogen and phosphorus loads into water bodies from animal waste and fertilizer applied to agricultural fields (NSTC, 2003).

OFWS was introduced to prevent the downstream flow of pollutants from agricultural lands that threaten the quality of nearby water bodies. OFWS is also anticipated to ensure constant availability of irrigation water if strict drilling moratoriums on wells are implemented in Mississippi in the future. Drilling bans have been employed by some states (e.g. California, Florida, Georgia, Nebraska) to reduce the stress on groundwater resources. Although Mississippi producers need to obtain permits from the Mississippi Department of Environmental Quality, Office of Land and Water Resources and Environmental Quality Permit Board (EQPB) before they can drill wells with over a 6-inch casing, the concerns about water table declines are likely to trigger implementation of stricter drilling regulations in the near future.

OFWS has recently been growing in popularity in Mississippi, especially in the Delta and Blackland Prairie regions in East Mississippi. Construction of TWR is popular in the Delta, while the geography of the land in East Mississippi allows farmers to directly capture runoff water into storage ponds. The concern about reliable sources of water for irrigation in Mississippi is prominent in the Backland Prairie region of East Mississippi. The region has groundwater levels ranging between 200 feet and 295 feet deep (Ouyang et al, 2016). Poor access to groundwater has historically restricted crop producers in East Mississippi to dryland production. However, the increase in uncertainty in rainfall patterns is gradually driving producers in the region to supplement rainfall with irrigation during the growing season. To obtain enough water for irrigation, crop producers in East Mississippi have to drill over 1,000 feet in many areas to access water (personal communication), compared to about 200 feet in the Delta region. The cost of drilling this deep in Eastern Mississippi can be as high as $175,000 (Delta Farm Press, 2012), and successfully finding water isn’t always guaranteed. Mississippi receives enough rainfall of about 55 inches annually, but the lack of access to groundwater coupled with only 30 percent of annual rainfall occurring during optimal crop growing periods (Kebede et al. 2014) increases the uncertainty of crop producers meeting their production goals.

Studies that have focused on the use of OFWS in Mississippi have reported multiple benefits such as reducing the pressure on groundwater, protecting water bodies from pollutants from agricultural fields, nutrient recycling, and more. However, only a small percentage of these studies in Mississippi have analyzed the economics and associated risk of making such an irrigation investment. Existing feasibility studies (e.g Falconer, Luis and Krutz, 2015) in the Delta region do not support the construction of OFWS. However, as mentioned previously, East Mississippi crop producers are resorting to the use of OFWS as an alternative to a cost prohibitive well system. But, no effort has been devoted to analyze the economics of investing in OFWS under East Mississippi growing conditions. The few existing studies on the profitability of investing in an OFWS in the southeastern United States also have not included the risk associated with making such an investment. However, the decision to make such an investment will be very much dependent on how a decision maker perceives the risk involved.

1.2 Objectives

The primary objective of this study is to determine if it is economically sound to invest in an OFWS under East Mississippi growing conditions. This is achieved by simulating the net present value of an OFWS over an assumed useful life of twenty five years. This study also seeks to determine producer's preference between irrigating from an OFWS and rain-fed production under different risk tolerance levels.

1.3 Significance of Study

Agriculture is the leading industry in Mississippi. The agriculture industry in Mississippi is worth about $7.6 billion and employs 29 percent of the state's work force (MDAC, 2016). Among the top twenty in corn, soybean and cotton producing states in the U.S., Mississippi ranked 14th (97 million bushels), 20th (120 million bushels) and 3rd (1.1 million bushels) for soybean, corn and cotton production in 2016, respectively. In fact, Mississippi was in the top twenty in the production of fifteen agricultural commodities (Mississippi Ag Statistics Service, 2016). In 2016, soybean, corn and cotton contributed $1 billion, $436 and $442 million, respectively to the state's economy (MDAC, 2016).

Though the bulk of crop production takes place in the Delta region, considerable attention should be given to production practices in other areas of the state such as the Blackland Prairie region in East Mississippi. For example, Noxubee county and Lowndes county produced between 1,000,000 to 4,000,000 bushels of corn in 2015, and Lee, Chickasaw and Monroe counties each produced between 1,000,000 to 5,000,000 bushels of soybean in the same year (Mississippi Ag Statistics Service, 2016). These yield outputs are comparable to production from some counties in the Delta region despite more favorable growing conditions in the Delta.

Irrigated agriculture in Mississippi plays a vital role in reducing crop production losses from the combination of a lack of rainfall and high temperatures between the months of April and September when major crops such as corn and soybean are grown. The gradual shift from the use the groundwater and deep wells to the use of OFWS as a source of irrigation water makes this study imperative in determining whether investing in an OFWS is worthwhile, especially for crop producers in East Mississippi who have limited access to reliable irrigation water sources.

The profitability of investing in irrigation have been well researched in humid areas, but most of the existing studies have focused primarily on irrigation techniques rather than the source of irrigation water. Dalton, Porter, and Window, (2004) reports on the significance of accounting for the cost of developing water source for irrigation. They explain that the cost of water source should not be ignored as it plays a vital role in the decision to either make an irrigation investment or not. Others who have taken into consideration the cost of developing a water source for irrigation mostly assume a groundwater-based system, but, the use of groundwater irrigation systems can be very expensive due to the continuous decline in water tables. This has led to the increase in the depth of drilling before finding a sufficient and reliable water source for irrigation, further driving up costs. This research analyzes the economics of an OFWS, which serves as an alternative to a well system, and will be a valuable information source to crop producers who are considering whether to make an irrigation investment or not.

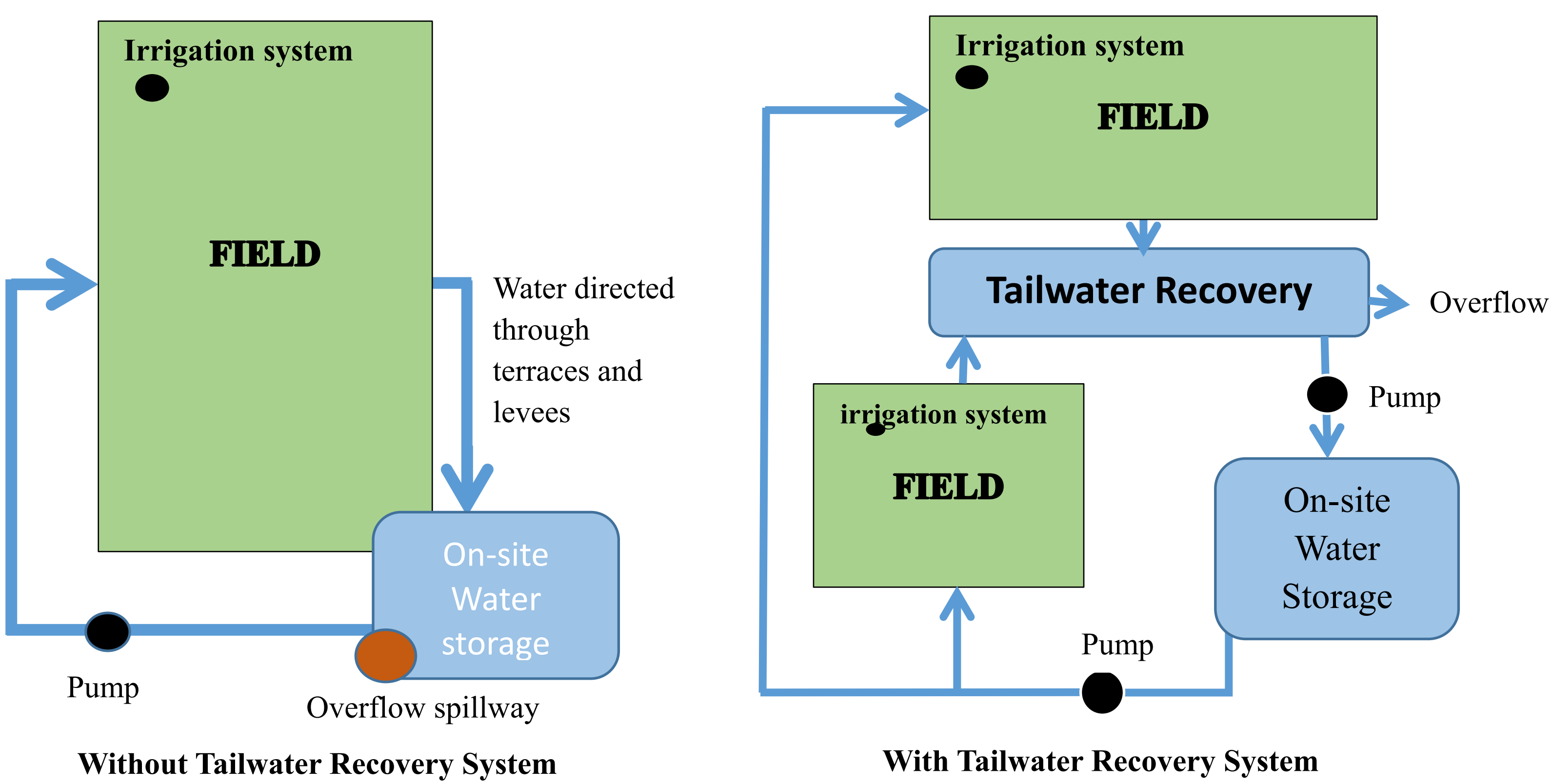

Figure 1.3 Schematic diagram of OFWS

CHAPTER II

REVIEW OF LITERITURE

Generally, irrigation is practiced to reduce the risk of yield and profit losses caused by insufficient rainfall. This research determines whether investing in an on-farm water storage system as a source of irrigation water is a feasible alternative for mitigating farm level risk. This chapter presents a general overview of alternative strategies for reducing farm level risk, the use of on-farm water storage, and existing research on its profitability.

2.1 Risk in Farming

Risk can be defined as the likelihood of a loss (Harwood et al. 1999), and occurs when the outcome of a decision is not known before a decision is made (Kahan, 2008). Farming is an inherently risky business associated with several different types of risks. Sources of risk in farming are usually categorized into five areas: market, production, human, financial and institutional risks (Kahan, 2013). Uncertain weather and performance of crops and livestock causes production risk. Market risk is caused by the unpredictable prices of outputs and inputs. Institutional risk is due to changes in government policies. Personal or human risk is ascribable to uncertain life events and financial risks resulting from different methods of financing the farm business (OECD, 2009). Uncertainties in these factors cause significant changes in farm incomes (USDA Economic Research Service, 2016).

2.2 Risk Management Strategies

Risk management is crucial to the success of agriculture due to the changing structure of the agricultural industry (Dorollette, 2009; Boehje, 2007). Actions taken by market participants (e.g. forward contracting, hedging and diversification) and public policies (e.g. farm bill programs) are among the commonly used strategies used to manage risk in farming (USDA Economic Research Service, 2016). On-farm practices such as irrigation have also been identified as an effective risk management strategy (Lin, Mullen and Hoogenboom, 2008; Dalton, Porter, and Window, 2004; Vandeveer et al. 1989; Boggess et al 1983; Boggess and Amerling 1983). However, the high initial investment cost makes irrigation risky. Boggess and Amerling (1983) noted that farmers who practice irrigation are trading a reduction in production risk for more financial risk.

This research investigates whether the reduced production risk for irrigating from an OFWS outweighs the financial risk posed by the irrigation investment. Most producers employ a variety of management strategies to reduce risk. For example the combination of irrigation and crop insurance has been found to be an efficient risk management strategy (Barham et al. 2011). It should be noted that risk management strategies and tools do not prevent risk entirely, but help balance the risk and returns consistent with a producer's capacity to tolerate a wide range of outcomes. In other words, risk is inevitable in farming (Economic Research Service-USDA, 2016).

Since the passage of federal crop insurance act in 1980, crop insurance has proven to be an important risk management tool. The program has grown from an experimental program on major crops to an extended program that includes numerous crops across all regions of the United States. Crop insurance is regarded as an eminent risk management strategy that provides farmers with effective coverage against poor production (USDA-RMA, 2016). Under the two most common forms of crop insurance, farmers can either purchase yield protection (YP) or revenue protection (RP). YP protects producers against losses that are mainly caused by low yields. Specifically, producers are paid an indemnity if their actual yields fall below their guaranteed yields. A similar approach is used under RP where producers are paid when their actual revenues fall below their calculated guaranteed revenue. Guaranteed revenues are estimated as the product of the higher of harvest price and projected price, average production history, (APH) and the producer's chosen coverage level. The difference between these two policies is that a farmer insures the dollar value of the crop and number of harvested bushels under RP and YP respectively. Crop insurance has been identified as less superior to irrigation in mitigating weather related risk (Dalton, Porter, and Window, 2004), however the effectiveness of crop insurance in attenuating crop production risk is without doubt and is well documented in the field of farm risk management.

Another effective way of reducing variability in farm income is by diversifying the farm business. Enterprise diversification assumes income from a combination of crop production and livestock, different crops, different varieties of the same crop or any other enterprise combination. As a risk management tool, the basic idea is to offset low income from one enterprise with high incomes from another enterprise (USDA Economic Research Service, 2016). Kay, Edward and Duffy, (2008) noted that enterprise diversification can significantly reduce variability in farm income if prices and yields are not low or high at the same time. That is, the effectiveness of diversification is dependent on the correlation between returns from selected enterprises. A positive correlation of prices and yield among selected enterprises leads to little reduction in farm income variation and a negative correlation between these values for selected enterprises leads to more reduction in farm income variability (Kay, Edward and Duffy, 2008). Though there are correlation concerns, the likelihood of having all enterprises and operations being affected by the same changing situations is lower (Kahan, 2008).

Forward contracts can significantly reduce price risk by providing farmers with known prices and other detailed terms in a contract. Farmers can enter into either a marketing or production contract. Under production contracts, producers grant ownership to the contractor (buyer). The buyer then restricts the producer to specific production processes, inputs and the quality and quantity of output to be delivered. Production contracts detail the guaranteed compensation a producer will be given after delivering output as required by the buyer (Harwood et al. 1999). A market contracts is when a producer and a buyer agree in advance on a guaranteed price for sale of a product before the harvest or marketing period. Market contracts between grain producers and grain elevators are quite common across the country. Kahan, (2008) noted that a guaranteed price reduces the risk of receiving lower prices at harvest which might not recover their cost of production.

Hedging utilizes futures or options contracts to mitigate price-level risk prior to an anticipated cash transaction. Hedging involves either purchasing future contracts (long hedge) or selling futures contracts (short hedge). Harwood et al. (1999) noted that farmers hedge under several different scenarios including storage, production and the expectation of future purchases. Under hedging, producers can obtain approximately their expected returns from storage, production and expected cost of inputs because the losses or gains in the value of cash commodity due to price changes tend to be offset by the losses or gain in the value of future positions (Harwood et al. 1999), leaving only basis risk for producers to be concerned with. According to Harwood et al. (1999), hedging involves costs that appear modest compared with the risk reduction for most farmers.

The effectiveness and importance of these mentioned strategies in mitigating price, yield and revenue risk has been confirmed in several studies. Regardless of the risk management strategies available, the ability to withstand risk differs from producer to producer. The choice of a strategy is dependent on available alternatives (Velandia et al. 2009; Coble, Heifner and Zuniga, 2000). Some of the mentioned alternatives can reduce more than one risk whiles others deal with a single type of risk (USDA Economic Research Service, 2016).

2.2.1 Irrigation as a Risk Management Strategy

Considerable attention has been given to the use of irrigation as a risk management tool. With the exception of a few studies such as DeJonge, Kaleita and Thorp (2007), most studies concerning the use of irrigation as a risk management tool have confirmed its effectiveness. DeJonge, Kaleita and Thorp (2007) examined the net returns of irrigation production in Iowa. They assumed the use of a center pivot irrigation system for corn production and found that at a baseline corn price of $2.00/bu, irrigation is unprofitable despite increases in corn yield. However, Boyer et al. (2014) points out that the returns and uncertainty of irrigating corn is likely to change due to increased corn prices in recent years. For example, nearby corn futures prices have not been below $2.00/bu since 2005, and had not been below $3.00/bu from 2006 until fall 2016.

In 1983, Boggess and Amerling and Boggess et al. used a bio-economic simulation model to simulate the risk and returns of irrigating with low and medium pressured center pivot irrigation systems (CPIS). Findings from their research show that the use of irrigation as a risk management strategy significantly reduces the variability in crop yields and produces consistent crop yields and returns. Generally, irrigation is desirable because of its great potential to mitigate variability in net returns and profits (Epperson, Hook, and Mustafa, 1993: Boggess et al. 1983). However, a fall in crop prices below a certain threshold could lead to losses even under irrigated production (Boggess et al. 1983).

As mentioned previously, diversification is one of the most commonly used risk management strategies. According to Vandeveer, Paxton and Lavergne (1989), investing in irrigation provides potential diversification advantages by increasing the range of production possibilities. In their research, they used a portfolio approach to analyze the effect of irrigation income on farm risk return by comparing it to dryland conditions at a common risk level. They found that irrigation conditions provide diversification benefits that are large enough to offset the risk of irrigation investment and also increases the credit capacity of a farm.

The impact of weather derivatives and different irrigation levels on reducing farm level risk was analyzed by Lin, Mullen and Hogeboom (2008). Results from their study show that optimal irrigation is an effective farm-level risk management strategy for different producer risk aversion levels and different production soil types. In 2004, Dalton, Porter, and Window, compared federal crop insurance programs as risk management tools to irrigation. Findings from their study indicate that premium subsidies and production guarantee levels from federal crop insurance programs are less efficient in mitigating weather-related risk as compared to the use of irrigation. The efficiency of irrigation is, however, dependent on irrigation technology and irrigated acres. They report that capital intensive irrigation technology reduces profitability on small fields, but under extreme producer risk aversion levels, a capital intensive irrigation technology is most preferred.

The irrigation investment cost in this study includes both the cost of developing a water source for irrigation (an irrigation reservoir) and an irrigation technique (center pivot irrigation system (CPIS)). CPIS is the most common irrigation technology in the United States due to its high irrigation efficiency. Apart from its high efficiency, CPIS offers benefits such as reduced labor costs, uniform water application, easier application of agro-chemicals, and reliability (Sinobas, 2017). Despite these advantages, CPIS has a high initial investment cost. Studies such as Lamm et al. (2015), Williams et al. (1996) and O'Brien et al. (1998) have confirmed the economic viability of investing in a CPIS. Returns from CPIS irrigated farms are comparatively higher than that of other commonly used irrigation technologies (Lamm et al. 2015; O'Brien et al. 1998). However, returns are very sensitive to crop prices, yield, field size and initial investment cost.

Recently, Boyer et al. (2014) used partial budgets to determine the additional revenue and additional cost incurred for irrigating using a CPIS in Western Tennessee. Assuming a 20 year useful life for a non-towable CPIS, simulated net present values from their study indicated that there is at least an 87 percent chance of obtaining a positive net present value for 125 acres and above when post-2006 corn prices prevail. However, zero net present value was obtained for 60, 125 and 200 irrigated acres under pre 2006 corn prices. Their net present value estimates were sensitive to the cost of energy sources used to pump irrigation water from a well system.

Though the abovementioned studies give an extended understanding of the feasibility of irrigation investment and its potential as a risk management strategy, the sources of water used or assumed in most of them are wells and direct withdraws from rivers and streams. This research looks at a more conservative storage reservoir as a water source for irrigation. The source of water is important in determining the feasibility of an irrigation system. For example, Dalton, Porter, and Window (2004) point out that the cost of developing a water source for irrigation considered in their study is likely to be an underestimation because it is based on historical sources of irrigation water. They use $65,000 and $115,000 to reflect recent cost of developing water sources such as wells and ponds.

2.3 On-Farm Water Storage (OFWS) in the Southeastern United States

As explained previously, irrigation reservoirs and tailwater recovery systems (TWS) are designed to capture, store and convey irrigation and rainfall runoff for reuse in irrigation. The purpose of this irrigation systems is to improve water use efficiency, provide reliable irrigation water, improve offsite water quality and reduce energy use (NRCS-CPS, 2014). Generally, OFWS serves two purposes: economic and conservation (Moore, Pierce and Farris, 2015). The use of on-farm reservoirs or ponds to capture and re-use surface water for agriculture was identified decades ago as a dependable and economical source of water to meet the growing demand of water for agricultural purposes. On-farm reservoirs have emerged as an important source of irrigation water, especially in the east where irrigation enterprises are not as well defined as in the west

(USDA-NRCS, 1997). Though it has long been in existence, the practice of capturing surface water for agricultural has been more recent in the southeastern United States, particularly in areas such as Mississippi and Arkansas (Czarnecki, Omer and Dyer, 2016).

In 2010, the NRCS, together with their partners, launched the Mississippi River Basin Healthy Watersheds Initiative (MRBI) to prevent nutrient loading from agricultural lands, improve water quality, conserve wildlife habitat and improve agricultural productivity in selected watersheds. The initiative uses a number of Farm Bill programs (e.g. environmental quality incentive program (EQIP) and wildlife habitat incentive program (WHIP)) to help producers and landowners adopt conservative measures (Progress Report MRBI, 2016). The NRCS has since been working closely with farmers, ranchers and landowners in these selected states to implement conservation measures. Eligible farmers in the selected states have been receiving technical and financial support from NRCS. As of 2013 the NRCS through MRBI had implemented conservation systems on over 800,000 acres in its project area and has dedicated $327 million in financial and technical assistance to eligible producers (Progress Report MRBI, 2013). According to the 2016 report, NRCS envisions a reduction of 1.9 million tons of sediments, 9.5 million pounds nitrogen and 2.85 million pounds of phosphorus losses from all crop land under MRBI by 2018 (Progress Report MRBI, 2016).

Mississippi, Arkansas, Tennessee, Kentucky and Louisiana are the southeastern states among the thirteen states under MRBI. OFWS began to gain popularity in these southeastern states after the MRBI initiative. NRCS has financially supported the construction of over 200 TWR systems in Mississippi (Czarnecki et al. 2016). Construction of OFWS is under the practice code 436 or 447 (NRCS-CPS, 2014).

2.4 The Economics of On-Farm Water Storage (OFWS)

Most of the existing studies concerning the use of OFWS have primarily focused on its environmental impacts and have not applied economic tools to determine its profitability. Few studies have been conducted to assess the profitability of investing in an OFWS in humid regions. For example, no attention has been given to the economics of investing in an OFWS in East Mississippi though the system is gradually gaining acceptance by crop producers in the region. To the best of our knowledge, the only study in Mississippi that has focused on the economic feasibility of the system is Falconer, Lewis and Krutz, (2015). Falconer, Lewis and Krutz, (2015) compared the net present value of estimated returns for corn and soybean from rain-fed, furrow irrigated production and center pivot irrigated productions, using OFWS as the source of irrigation water in the Mississippi Delta. Their results showed that it is not economically viable for corn and soybean producers in the Delta region to invest in an OFWS due to its high initial cost and the significant portion of productive cropland needed for its installation. Potential cost savings for recycled nutrients and other environmental benefits were not accounted for in their study.

Other existing studies that have focused on the economics of OFWS include Wailes et al. (2003), Popp et al. (2003) and Boulden et al. (2004). Wailes et al. (2003) used Modified Arkansas Off-stream Reservoirs Analysis (MARORA) to determine the economic feasibility of investing in an on-farm reservoir for a 320-acre cultivated area under a rice and soybean rotation. Using a discount rate of 8 percent over a 30 years useful life, MARORA was used to simulate the net present value of an OFWS for relatively adequate (50-ft initial saturated) and inadequate (30-ft initial saturated) groundwater levels. For relatively inadequate groundwater situations they estimated a net present value of $283 per acre to land for soybean production without irrigating from a reservoir compared to about $2,213 with a reservoir. On the whole, Wailes et al. (2003) showed that it is not economically sound to invest in an OFWS when groundwater levels are adequate, as it will occupy valuable production land over the assumed useful life; similar to results found by Popp et al. (2003). According to Popp et al. (2003) the profitability of OFWS in adequate groundwater levels can be increased by using a more efficient irrigation system. Providing producers with cost share opportunities will also increase profitability significantly (Popp et al. 2003).

The studies by Popp et al. (2003) and Wailes et al. (2003) were both conducted in Eastern Arkansas. Eastern Arkansas is part of the Mississippi Delta region, hence, the production conditions used in both studies are representative of the Mississippi Delta region (Popp et al. 2003). For this reason, the findings from these studies should align with results from Falconer, Lewis and Krutz (2015).

Boulden et al. (2004) used a benefit-cost ratio (BCR) and internal rate of return (IRR) approach to analyze the economic feasibility of an OFWS compared to that of a groundwater well system. At an interest rate of twenty five percent, results from their study shows that investing in an OFWS generates a BCR of about five times that of a well system. Not surprisingly, this is even more pronounced when the interest rates are reduced. An IRR greater than 1 and 0.3467 was obtained for OFWS and groundwater well systems respectively. The higher present value estimates obtained for OFWS was attributed to the ecological services, decreased nutrients to waterways, topsoil saved and other merits that come with use OFWS.

Though existing studies have confirmed OFWS to be more economical and conservative than other sources of irrigation water, others believe it is still not economically sound to invest in an OFWS, especially for areas with high groundwater levels. Despite these mixed results, findings from the existing work favor the construction of OFWS when groundwater levels are low. While prior research has focused on OFWS in the Delta region, it is difficult to draw conclusions for areas outside of the Delta (e.g. East Mississippi) because of the dissimilarities in weather conditions, soil, construction cost and other management practices might affect the net returns for producers. Hence, the need to determine the profitability of investing in an OFWS for a variety of growing conditions.

2.5 Benefits of On-Farm Water Storage (OFWS)

As mentioned previously, construction of OFWS comes with multiple benefits such as an increase in irrigation efficiency, reduced cost of irrigation water, reduced energy use, nutrient recycling, reduced stress on groundwater resources and improvement of offsite water quality. Agricultural runoff accounts for about 90.5 percent of the total nitrogen contamination flowing into the Gulf of Mexico (Doering et al. 1999), and is the leading cause of nonpoint-source pollution in the United States (EPA, 2002). Nitrogen and phosphorus are essential inputs to profitable crop production, but not all of these nutrients applied to the land are taken up by crops. Some are lost to the environment through runoff, which contributes to offsite water quality problems such as hypoxia and eutrophication (ESA, 2012). It is therefore important to put in conservation measures to minimize agricultural runoff erosion and its subsequent impacts on the environment.

Best management practices (BMP's) involve soil and water conservation practices and other management activities that are developed as effective and practical tools for environmental protection in a particular region (Sharpley et al. 2006). OFWS are considered a BMP because they reduce pressure on groundwater by providing irrigation water while also conserving the environment and its ecosystem by impeding soil, nutrient and sediments from flowing off the field through runoff. Apart from its potential of reducing the stress on groundwater resources (Ouyang et al. 2016), studies such as Pérez-Gutiérrez, Paz and Tagert (2017), Moore, Pierce and Farris (2015), Carruth et al. (2014), Kirmeyer III, et al. (2013) and Popp et al. (2003) have shown that OFWS systems have the capacity to capture and store potential contaminants (fertilizer, pesticides, herbicides, crop residues, etc.) that threaten the water quality of nearby water bodies, especially when a water storage reservoir is used in tandem with a TWR system. Surprisingly, toxicity tests by Moore, Pierce and Farris, (2015) show that captured runoff may pose no significant threats to receiving systems in the case of downstream flow.

Popp et al. (2003) modeled Eastern Arkansas production conditions in environmental policy-integrated climate (EPIC) and MARORA models to determine the environmental benefits of OFWS. EPIC and MARORA estimated that a significant amount of sediments and active nutrients could move off the field in the absence of OFWS (Table 2.1). The effectiveness of OFWS in preventing the off-field movements of sediments and nutrients is dependent on three factors: the magnitude of run-off events, volume of water in the reservoir and influx of effluent from different fields (Kirmeyer III et al. 2013). Coincidentally, the effectiveness of OFWS in preventing the downstream flow of nutrients and sediments may be reduced significantly when it is needed the most (Carruth et al. 2014). According to Carruth et al. (2014), an increase in nitrogen levels in grabbed samples from an OFWS occurs during fertilizer application and tillage periods for corn and soybean fields in Northwestern Mississippi. This means OFWS systems are needed during these periods to prevent downstream flow of nutrients and sediments from fertilized and tilled fields. At the same time rainfall received during these periods is high, which increases runoff events and causes overflow of storage ponds leading to downstream movement of runoff water from the field.

Table 2.1 Potential annual per acre pesticide and nutrient movement off-field

Sediment (tons)	1.08
Organic N (lbs.)	3.79
NO_3 (lbs.)	26.20
P (lbs.)	1.41
Pendmethalin (lbs.)	0.00381
Propanil (lbs.)	0.00198
Flauzifop-P-butyl (lbs.)	0.00010

Source Popp et al. (2003)

Findings from Ouyang et al. (2016) showed that about 33,074,466 in^3/ha of groundwater can be conserved annually if irrigation reservoirs are constructed with appropriate dimensions. They used a STELLA (Structural Thinking Experimental Learning Laboratory with Animation) model to analyze the hydrological processes and pond size ratio of OFWS. Results from their study indicate that a pond size of 1-ha with a depth of 78.7 inches is reasonable to irrigate an 18-ha of soybean in East Mississippi. Ouyang et al. (2017) found a reasonable pond size ratio of 1:7 in the Delta region, which has high ground water levels compared to the East.

Between 1987 and 2014, the Yazoo Mississippi Delta Joint Management District (YMD) reported about $3.0084339 \cdot 10^{14}$ in^3/year of groundwater loss in the Delta (YMD, 2015). According to Ouyang et al. (2016), if the stated pond size ratio is taken into consideration for 10,000 ha irrigated soybean area, then irrigating from an on-site pond could reduce groundwater use by 11%. Economically, the environmental benefits obtained from on-site water storage systems make it more attractive when compared to well systems (Boulden et al. 2004).

2.6 Risk Ranking

After simulating the outcomes of risky scenarios, a decision maker is faced with the task of selecting the best scenario. This study compares the net present value distribution of irrigating from an on-farm water storage to that of rain-fed production. One of the objectives is to conduct a risk assessment to determine decision maker's preference between the two scenarios. This section summarizes the procedures that can be used to determine a decision maker's preference among alternatives.

2.6.1 Summary Statistics

Estimates such as the mean, coefficient of variation, mean variance and standard deviation can be used to rank different alternatives. Using the simulated means of output variables such as net present values is simple and based on a more-is-preferred-to-less assumption. The means procedure assumes decision makers are neither risk averse nor risk seeking, hence, disregarding the risk associated with each alternative. The advantages of stochastic simulation are therefore lost when only the means are used for ranking (Richardson, 2008). Unlike the means procedure, alternatives with smaller standard deviations are preferred and ranking is based on strict absolute risk.

The mean variance procedure takes into consideration both the mean of the output variable and its standard deviation. This procedure for ranking alternatives is dependent upon a decision maker's preference for the tradeoff between the output variable and the standard deviation. Generally, the best scenario will have the highest output variable and the smallest standard deviation. Coefficient of variation is the ratio of the standard deviation and the mean of the output variable of interest. Coefficient of variation takes into consideration the average risk of each alternative and it gives clearly defined ranks in the absence of ties (Richardson, 2008). Like the standard deviation, the alternative with the lowest coefficient of variation is most preferred.

The abovementioned procedures are based on summary statistics of an output variable. Ranking of risky alternatives based on simulated summary statistics may be infeasible when the alternatives with the highest means do not have the lowest coefficient of variations or standard deviations. Producers tend to be risk averse and are concerned about the downside risk associated with their decisions. The downside risk of some alternatives or strategies may be ignored if rankings are based on simulated summary statistics.

Generally, the use of summary statistics for ranking risky alternatives is less superior to procedures that use the complete distribution of an output variable. Cumulative probability function (CDF) and probability density functions (PDF) are commonly used to show the range of possible outcomes for risky alternatives by using the complete distributions of simulated results. For example, on a CDF chart the CDF farthest to the left is least preferred because at each probability level it generates lower rates of returns compared to those further to the right. An expected utility function is needed, however, to unambiguously rank alternatives when there is crossing among CDFs (Richardson, 2008).

2.6.2 First and Second Degree Stochastic Dominance

In 1969, Hadar and Russell introduced the concepts of first-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) for ranking risky alternatives without knowledge of a decision maker's utility function. They explained that for any two distributions, FSD conditions are applicable when one cumulative distribution is partly or entirely above the other. FSD is not applicable when there is crossing among cumulative distributions. SSD is applicable when the area under one cumulative distribution is equal to or larger than that under other cumulative distributions. SSD allows for crossing among cumulative distributions (Chavas, 2004). Mathematically, given a net income or wealth (z) for probability functions (f) and (g), the cumulative distribution of f, $F(z)$ is first-degree stochastic dominant over $G(z)$ if $F(z)-G(z)\geq 0 \ \forall \ z$. Under SDD, $F(z)$ is preferred to $G(z)$ if $\int_b^a \left[G(s)-F(s)\right] ds \ \geq$ $0 \ \forall \ z$ in $\left[a,b\right]$ (Richardson, 2008). FSD works for all classes of decision makers. SSD has weaker conditions (Hadar and Russell, 1969) and assumes decision makers are risk averse and non-satiated in income (Chavas, 2004).

According to Chavas (2004), the ability to rank two alternatives using FSD and SSD indicates that there is enough information on which distribution would be preferred by a decision maker under weak assumptions or restrictions about their risk preferences.

Fewer restrictions made under FSD and SSD allow for unrealistic extreme risk aversion, which reduces their effectiveness in producing efficient sets (Hardaker et al. 2004). Chavas (2004) noted that allowing for extreme risk aversion would likely influence a decision maker to avoid a risky prospect, even if it yields higher returns. The reason is that FSD and SSD require the preferred distribution to start from the right of other distributions, hence, a distribution which shows higher returns but does not start from the right of other distributions could be avoided by a decision maker. Risk analysis should therefore be based on a more restricted range of risk aversion levels (Hardaker et al. 2004).

2.6.3 Stochastic Dominance with Respect to a Function

The concept of stochastic dominance with respect to a function (SDRF) was proposed by Meyer in 1977. Meyer's criterion is a general form of stochastic dominance which imposes a more restricted range of absolute risk aversion. SDRF ranks alternatives for a decision maker whose utility function is defined by a lower and an upper absolute risk aversion bound. Given two cumulative distributions $G(z)$ and $F(z)$, $F(z)$ is preferred to $G(z)$ when $\int_{l_1}^{l_2}\left[G(z)-F(z)\right] u'(z)dz \geq 0$, where l_1 and l_2 are the lower and upper risk aversion bounds, respectively (Richardson, 2008).

Pandey (1990) noted that SDRF allows for a tradeoff between incorrect rankings in explicit utility functions and incomplete rankings which are common in FSD and SSD. SDRF has been found to be more discriminating than FSD and SSD in ranking irrigation technology and irrigation strategies (Harris and Mapp, 1989; Pandey, 1990). In a study that compared water conserving irrigation strategies, three efficient irrigation strategies under FSD and SSD were reduced to one under SDRF (Harris and Mapp, 1986).

The limitation with SDRF is that it does not rank alternatives simultaneously, but instead determines a decision maker's preferred option between two paired risky alternatives with knowledge of only their lower and upper bounds of risk aversion (Hardaker et al., 2004). The discrimination strength of SDRF is dependent on l_1 and l_2 (Pandey 1990). Inconsistent ranking among alternatives may occur under SDRF if the l_1 and l_2 are set too far apart (Richardson, 2008).

Because SDRF is based on a pairwise comparison of distributions at lower and upper risk aversion bounds, its efficiency becomes questionable when the efficient set at a given risk aversion coefficient changes. McCarl (1998) proposed a solution to this by extending the SDRF beyond the pairwise comparison. According to McCarl (1998), break even risk root (BRAC) is the name of the risk aversion coefficient at which the efficient set changes. Multiple changes (crossing) in the efficient set results in multiple BRACs. Regardless of the number of BRACs, one alternative dominates the other for risk aversion coefficients lower than a BRAC, and the other dominates for risk aversion coefficient higher than the BRAC.

2.6.4 Stochastic Efficiency with Respect to a Function

As an improvement on SDRF, Hardaker et al. (2004) proposed the concept of stochastic efficiency with respect to a function (SERF). SERF ranks alternatives by specifying the certainty equivalent (CE) of each alternative at different risk aversion coefficients. Based on a utility function, the CE is the value at which a decision maker is indifferent between the value and the risky outcome. SERF can be applied to any utility function for which the inverse form can be estimated based on ranges in absolute and relative risk aversion coefficients. That is $CE(w, r_i(w)) = U^{-1}(w, r_i(w)),$ where $r_i(w)$ is a risk aversion function evaluated between the lower and upper bounds, and U^{-1} is the inverse utility function (Hardaker et al. 2004).

Some advantages of SERF over SDRF are explained in Hardaker et al. (2004). One advantage of SERF is that it has the potential of identifying smaller efficient sets which are likely to be ignored under SDRF due to the selection of only pairwise dominated alternatives (Hardaker et al. 2004). Efficient sets are identified in SERF procedures by selecting utility efficient alternatives and comparing them to other alternatives simultaneously under consideration. In other words, SERF evaluates the certainty equivalent at many risk aversion coefficients between the lower and upper bounds, unlike the SDRF which takes into consideration only the two extreme risk aversion coefficients (Richardson, 2008). Another advantage of SERF is that it provides graphical representation of outputs, which makes it much easier to interpret. The algorithm of SERF is included in simetar (Richardson, 2008).

All of these procedures are relevant in risk assessment discussions. Though the risk assessment procedures based on summary statistics (mean, standard deviations, mean variance, minimum and maximum values, etc.) are less superior to other approaches, they are still useful in ranking risky alternatives. In many cases, the summary statistics of output variables of interest are reported concurrently with stochastic dominance and SERF outputs (e.g. Boyer et al. 2015; Tzouramani et al. 2014; Barham et al. 2011; Johnson and Bordovsky, 2009). The use of SERF procedures has become popular in recent risk analysis studies as the conventional SDRF is comparatively less transparent and less discriminating.

The inability to rank alternatives under FSD due to crossing sometimes makes it difficult to use when alternatives have comparable output variables (e.g income). Richardson and Outlaw (2008) noted that there is at least one crossing among CDFs for risky alternatives under most real-life situations. Though SSD allows for multiple crossings (Chavas, 2004), extensive crossing among several alternatives makes it difficult to determine the best alternative for a risk averse decision maker. Multiple crossings among alternatives is one reason why most recent studies have resorted to the use of SERF procedures. For instance, Barham et al. (2011) used both stochastic dominance and SERF procedures to determine Texas cotton producers' preference between different irrigation levels and rain-fed production. They had only three out of sixteen scenarios (net return probability distributions of different production levels with and without crop insurance) which could easily be assessed under FSD. Multiple crossing among the remaining scenarios made it difficult to use SSD. Similarly, Boyer et al. (2015) used SERF analysis due to extensive crossing among sixteen risk management strategies which made it difficult to use FSD and SSD.

CHAPTER III

STUDY AREA AND DATA

This chapter provides background information about the various data and data sources used in the study. The chapter explains the reasons for using the reported data sets and how some data sets are developed. The chapter also includes a brief overview of the growing conditions in the study area.

3.1 Study Area

This research takes into account the size of a research farm located in Noxubee County in East Mississippi. The study site is located in Brookville, Mississippi, which is situated in the Middle Tombigbee Watershed. An irrigation reservoir of 17 acres in surface area and 25 feet deep is located at the southeast corner of the farm to serve as a water source for 339 acres. The reservoir is filled by precipitation and rainfall-runoff directed into the reservoir through a system of gravity-fed terraces. The reservoir supplies irrigation water for three center pivot irrigation systems on the farm. Soybean and corn are rotated on the field annually.

Noxubee County is located in the northeastern part of Mississippi with about a third of its area in the Blackland Prairie belt (USDA, 1910). Corn, cotton and soybean are the top crops grown in Noxubee County. Cropland in Noxubee County covers about 49.7% of the total county land area (USDA-NASS, 2012). The area is humid with ample rainfall of about 54 inches per year and an average daily temperature of about 18ºC (U.S

Climate, 2016). However, rainfall is unevenly distributed, with the driest months occurring during the growing season (Figure 3.3).

3.2 Weather Data

Daily precipitation as well as maximum and minimum temperatures for Noxubee County in East Mississippi were obtained from the Parameter-Elevation Relationship on Independent Slopes Model (PRISM) data base. Averages of the daily maximum and minimum temperatures were estimated to be the representative temperature for each day. Monthly temperatures were estimated as the mean of the daily temperatures within each month over the growing period. The growing season was fixed at five months, beginning in April and running through August for both corn and soybean. Weather conditions for these months are used because they mark the beginning of the usual active planting and harvesting dates of corn and soybean in Mississippi (USDA NASS, 2010). Monthly precipitation was estimated as the cumulative daily precipitation within each month.

3.3 Yield Data

Twenty three years (1992-2014) of annual average historical rain-fed and irrigated corn and soybean yield data for Noxubee County was obtained from the Risk Management Agency (RMA) of the USDA. RMA provides historical crop yields that are reflections of aggregated yields for a production area defined for a given state, county, and irrigation practice. RMA's crop yield data are available for crops for which crop insurance coverage is available for a given production area. A simple linear regression, $Y_{jt} = \alpha + \beta t$, was used to identify the influence of technical changes or trends in the actual county yields. Y_{jt} is the actual yield for crop j in the time t, α and β are the coefficients of the regression. Once identified, the actual yields were detrended to a base year of 2014. This means all estimated yields from the regression are converted to the base year equivalents. Yields are detrended as $Y_{jt}^{d} = \hat{Y}_{j2014} + (Y_{jt} - \hat{Y}_{jt})$. Where Y_{jt}^{d} is the expected value of the detrended yield. The superscript d is to show that the yields are detrended. $\hat{Y}_{j2014}$ is the predicted yield for the base year, and $\hat{Y}_{jt}$ is the predicted yield in each time period.

Farm level data are ideal for this study as the estimated returns and or revenues are assumed to be a reflection of farm-level management. However, due to the sparseness and difficulty in obtaining long-term series of farm level data, most researchers resort to the use of county level data as a representative for farm level data. The need for farm level yields for such studies becomes pronounced when individual farmers in a specific county or state under study are protecting their yields and or revenues under crop insurance policies. The reason is that some federal crop insurance policies and federal crop support groups are based on variations in farm level yields as noted by Cooper et al. (2009). Cooper et al. (2012) noted that crop insurance premiums for an individual farmer should be greatly influenced by the farmer's risk at his or her own farm level. Miranda (1991) shows that the use of area aggregated yields in crop insurance programs eliminates a portion of the risk faced by a producer.

Generally, to accurately capture farm level risk, farm level data is needed. But, due to the scarcity of farm level yields and the abundance of aggregated yields, some studies assume equal variability in farm level and aggregated yield distributions. Studies such as Porth, Seng-Tan and Zhu (2016), Godwin et al. (2012), Cooper et al. (2009) and

Coble and Dismukes (2008) have proposed different approaches for forecasting farm level yield distributions from readily available aggregated yields. We follow Cooper et al. (2009) by adding a normally distributed farm level noise to our simulated county yields to generate farm level yields as shown below. The standard deviation of Y_{jt}^{d}, $\sigma(Y_{jt}^{d})$ was used together with the ratio of standard deviation of farm level yield to county level yield (θ_j) to estimate the standard deviation of the farm level noise $(\sigma(\tau_j))$, which is added to the simulated county level yields to generate farm level yield data. Following Cooper et al. (2009), standard deviation of farm level noise is estimated using equation 1,

$$\sigma(\tau_j) = \sqrt{\left(\theta_j \cdot \sigma(Y_j^d)\right)^2 - v(Y_j^d)} \tag{4.1}$$

where $v(Y_j^d)$ is the variance of Y_{jt}^{d}. Let τ_j be the normally distributed farm level noise, $\tau_j \sim N\left(0, \sigma(\tau_j)\right)$, with a mean of 0 and standard deviation of $\sigma(\tau_j)$. θ_j is a 2016 estimated farm factor specific to Noxubee County and derived from USDA-RMA data.

3.4 Price Data

Twenty four (1992-2016) years of historical harvest time futures prices are obtained from the Livestock Marketing Information Center (LMIC). Crop insurance policies such as RP and YP are based on the harvest time and projected prices of a particular commodity. As explained below, the relationship between harvest time prices and yield is determined and maintained in generating harvest time price distributions.

For corn, historical December harvest time prices as observed in October were used, and November harvest time prices as observed in October were used for soybean. Historical December futures prices as observed in March are used as the planting time prices for corn, while the November futures price as observed in March is used as the planting time price for soybean. The differences between harvest time futures and planting time futures prices are used to simulate the variability in prices between planting and harvest time. This difference is then used to determine whether a crop insurance indemnity is triggered under revenue protection.

The harvest time futures price data is also used to correlate our yield to harvest time prices. The established correlation is used to simulate harvest time prices around a mean projected baseline price from the Food and Agricultural Policy and Research Institute (FAPRI). The FAPRI projected average price is based on existing market information and uses farm bill provisions, which are expected to follow the same agricultural policies in the future. The models used to estimate these baseline prices take into consideration the major uncertainties in the market (FAPRI, 2017).

3.5 Crop Insurance

Premiums paid for revenue projections were estimated at 70%, 75%, 80% and 85% coverage levels. An online cost calculator (Powered by Ag.analytic.org) was used to estimate crop insurance premiums for both irrigation and rain-fed productions. The Ag.analytic group provides an open access premium cost estimator for educational purposes. Premium estimates from Ag.analytic.org were randomly compared to that of the USDA's online cost calculator (RMA-USDA, 2016) to ensure consistency. The former was used for premium estimation because of its ability to estimate premiums for multiple coverage levels at a time.

Noxubee County was selected for calculating the premiums because of the location of the base irrigation reservoir under consideration. Premium payments were estimated using a range of crop prices. For corn, a minimum of $2.50/bu with $0.25/bu increments to a maximum $7.00/bu was used, while $0.50 increments from $7.00 to a maximum of $16.00/bu was used for soybean. Based on data availability, actual production history requires a minimum of four years and a maximum of ten years for every insurance unit. A four year (2010-2014) average corn and soybean yield for Noxubee County was used as the actual production history (APH).

3.6 Cost of Production

Estimates for corn and soybean production and the cost of operating a center pivot irrigation system for Non-Delta areas were obtained from the Mississippi State University (MSU) Planning Budget. The Department of Agricultural Economics, MSU provides annual enterprise budgets which report representative cost and returns for various crop productions in Mississippi (MSU Planning Budgets, 2017). These budgets are widely used for planning and making projections about expenses and returns. Estimates that are likely to vary based on farm conditions (e.g taxes and premium payments) are deliberately excluded from the planning budgets; hence these adjustments have to be made before appropriately using estimates from the MSU planning budgets.

This study uses representative estimates from the 2016 MSU planning budgets. We replicate these estimates for twenty five periods making necessary adjustments to account for year-to-year variations. For a given crop and production system (rain-fed or irrigation), annual per acre cost is estimated as the sum of variable expenses (v_t) and fixed expenses (r_t), where $\kappa_t = v_t + r_t$. $v_t = f$(chemicals, seed, hauling, soil test, consultancy, maintenance, labor, fuel) and $r_t = f$(implements, tractors, harvestors). The cost of labor and grain transportation are dependent on the projected yields each year. The planning budget provides an expected irrigation labor price of $1.84/acre/inch for Non-Delta areas. Due to the variability in the timing of precipitation in the study area, we assumed a minimum application amount of 6 in/acre for both crops. The cost of irrigation labor per acre was estimated as the product of 6 in/acre and the expected price of $1.84/acre/inch if the difference between a randomly drawn growing season precipitation and required precipitation for corn or soybean is less than 6 inches. However, if the difference is greater than 6 inches, then labor cost per acre becomes the product of the estimated difference and $1.84/acre/in. Seasonal water requirements for soybean and corn are dependent on planting dates and maturity group. Usually, 15 to 25 inches of water is required for soybean growth (Aganytime, 2017) while 20 to 24 inches is required for corn growth in Mississippi (Charles et al., 2005). Based on these ranges, we fixed the minimum required precipitation for corn and soybeans at 25 in/season.

The cost of constructing and maintaining a typical OFWS system in East Mississippi was provided by the owner of the study site (through personal communication). The ratio of cost of construction to reservoir size on the research farm was used to determine the cost of reservoir construction for 80-acre and 160-acre irrigated field sizes. Averages of various cost estimates are reported in Appendix D.

3.7 Savings for Nutrients Recycled

Not all nutrients applied to agricultural lands are used entirely by plants; some may be lost downstream through irrigation or rainfall run-off. Research has shown that on average, about 75%, 70%, and 85% of N, P, and K, respectively, are absorbed by corn at the time of tasseling (Johnston and Dowbenko, 2004). Hence, some percentage of the applied nutrients will be lost from the field at any point in time if run-off occurs. Doering et al. (1999) reported that 90.5 percent of total nitrogen that flows in the Gulf of Mexico is from agricultural lands. This finding would not have occurred if all the nutrients applied to the field were absorbed by the crops. Studies such as Tagert et al. (2015) and Popp et al. (2003) have reported that OFWS saves a significant amount of nutrients from flowing downstream, which means the possibility of recycling the captured nutrients could save producers a money annually on commercial fertilizer application.

Cost savings enjoyed by crop producers for nutrients recycled back onto the field from the use of OFWS is included in the net present value analysis to determine how it impacts the net present value estimates. Preliminary findings from Tagert et al. (2015) on the same research farm considered in this study indicate that the water storage system captures a significant amount of nutrients that would have gone downstream, but only a small percentage of the captured nutrients are recycled back onto the field. This is likely because the pump intake is at the bottom of the pond, where there are low dissolved oxygen levels that make conditions favorable for denitrification processes to occur. Grab samples were taken from the surface of the pond, where nutrient concentrations were higher. Concentrations of nitrate (NO_3), ammonia (NH_3), total nitrogen (TN) and dissolved orthophosphate was analyzed in three-week intervals during the 2015 growing season, and 53 tons of sediments were reportedly captured during the 2014 and 2015 growing season on the same research farm.

The Environmental Protection Agency (EPA) defines total nitrogen as the sum of the ammonia, reduced nitrogen and nitrate (EPA, 2013). Total nitrogen recycled in this study was measured as the sum of nitrate and ammonia concentrations from grab water samples from the center pivot over two monitoring periods reported by Tagert et al. (2015). Total phosphorus recycled is the sum of the phosphorus concentrations (soluble and adsorbed) from the center pivot irrigation system over the same monitoring period. Total nitrogen and phosphorus recycled were found to be 8.6 mg/L (1.95 lb/acre/inch) and 0.3 mg/L (0.07 lb/acre/inch), respectively. By multiplying the respective per acre estimates by the cost of nitrogen and phosphorus applied per acre for Non-Delta areas (reported in MSU Planning Budget, 2016), we found that $1.50/acre and $3.80/acre can be saved annually on phosphorus and nitrogen fertilization, respectively. This represents a total cost savings of $5.30/acre annually. The amount saved on recycled nutrients was accounted for in all years apart from the first year of investment based on the assumptions that irrigation from the storage system begins in subsequent years.

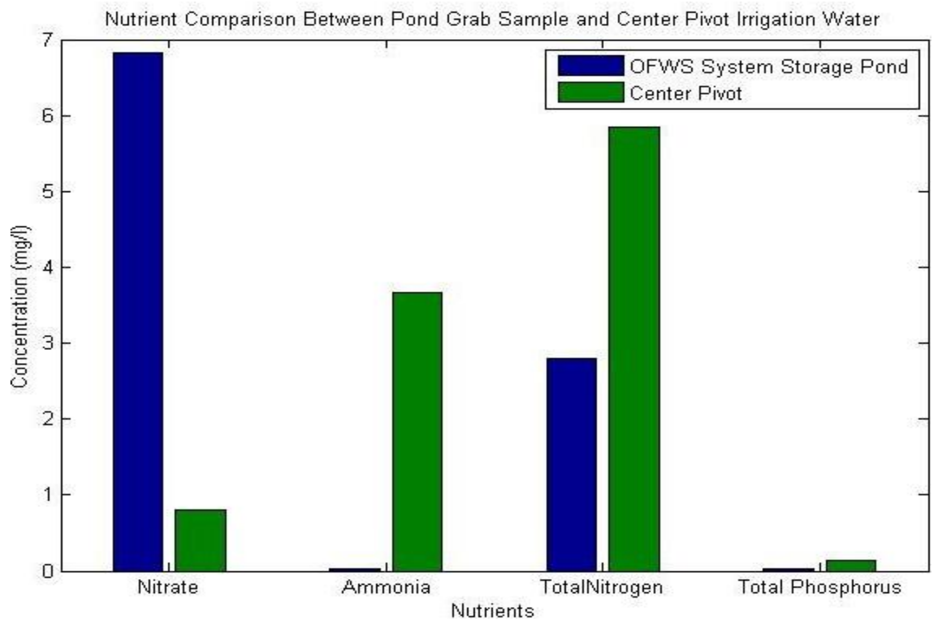

Figure 3.1 Nutrient comparison between grab samples from the pond and CPIS.

Source: Tagert et al. (2015)

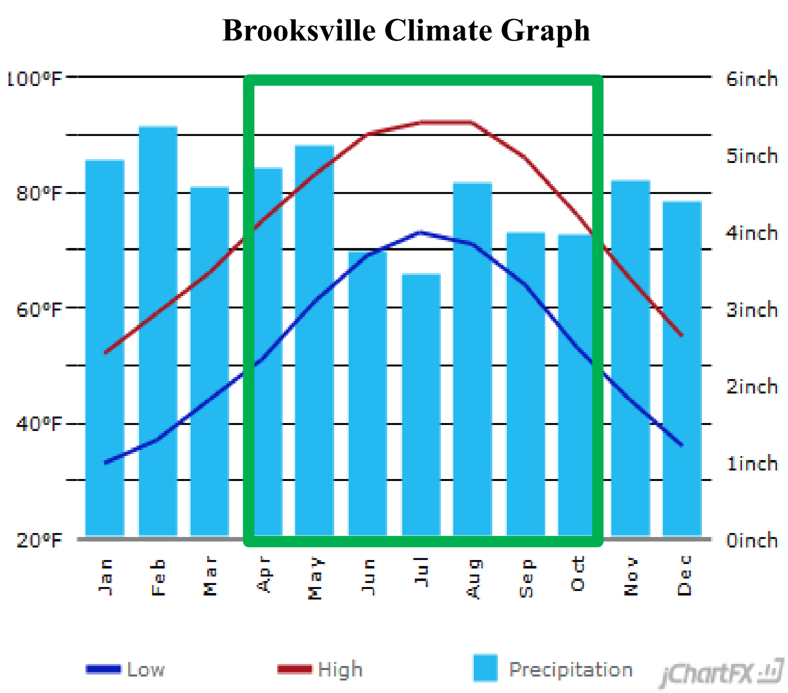

Figure 3.2 Climate Chart for Brooksville, Noxubee County, East Mississippi.

U.S Climate data, (2016)

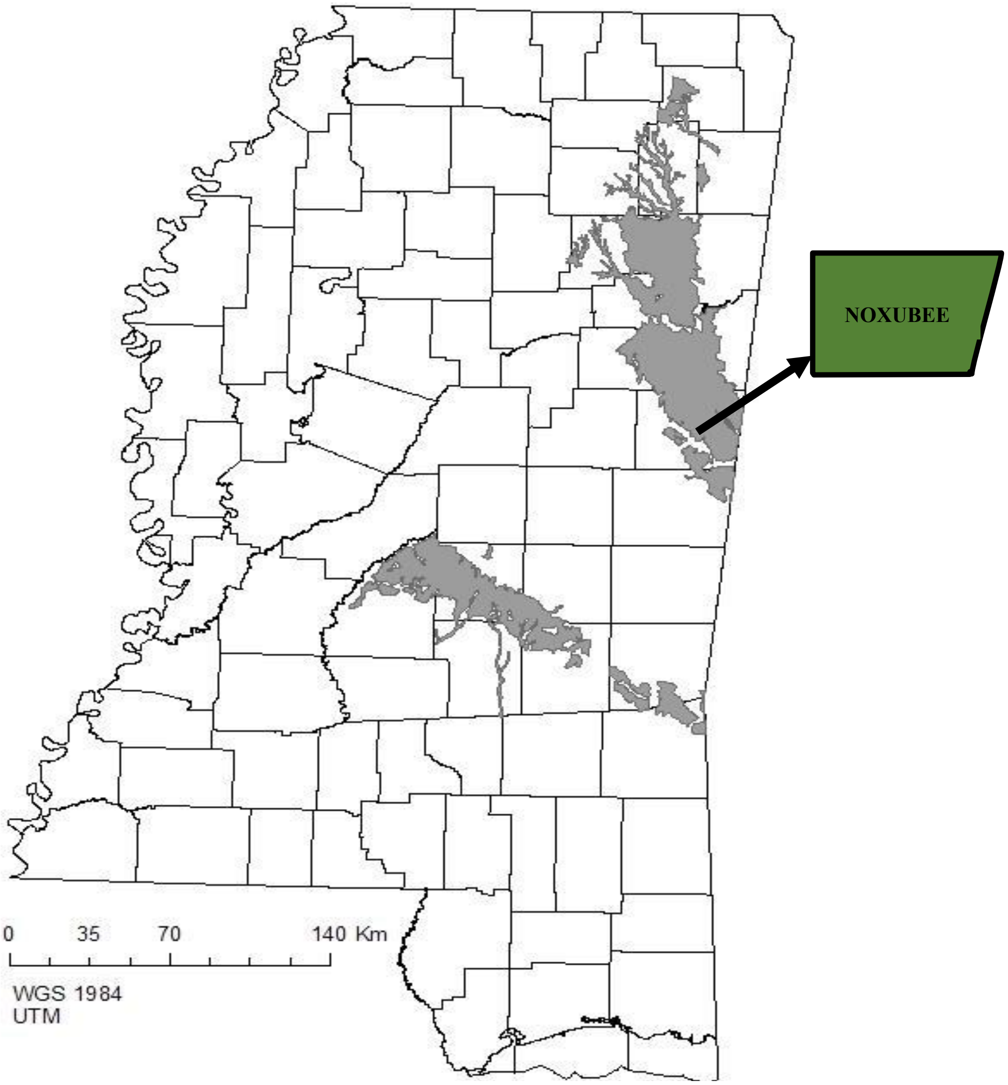

Figure 3.3 A map showing Mississippi counties and the Blackland Prairie Region.

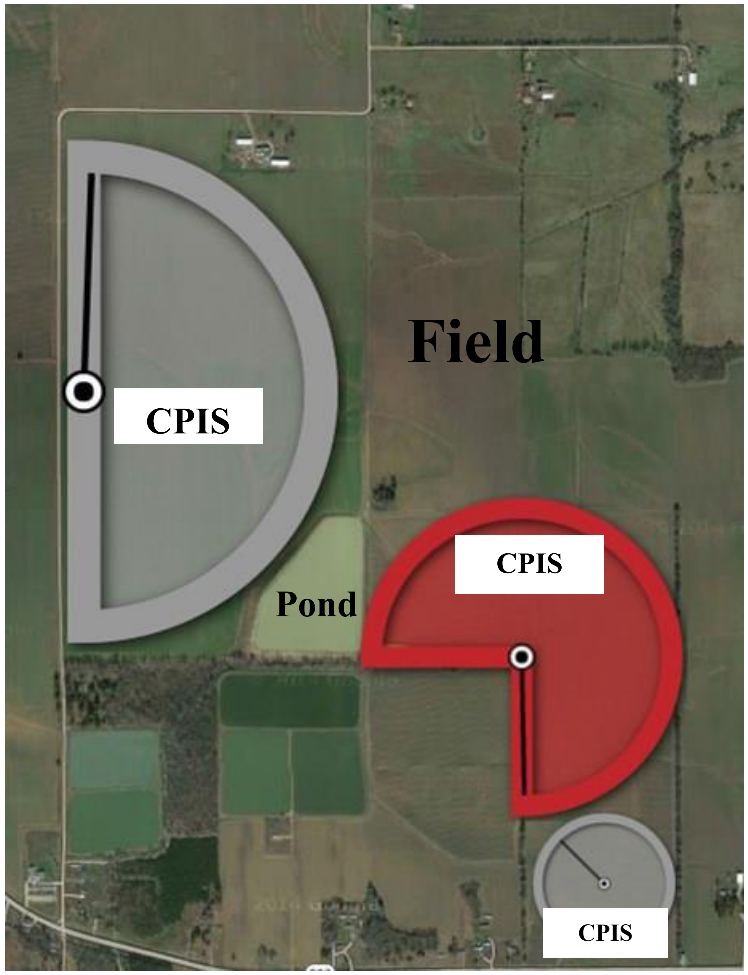

Figure 3.4 Schematic diagram of the study site in Brooksville, Noxubee.

Source: Ritesh Karki, (2015).

CHAPTER IV

METHODOLOGY

Chapter four discusses the approach used to achieve the previously mentioned objectives. This chapter starts with an explanation of stochastic simulation and the validation methods used to generate random variables for financial analysis. The methods used for ranking irrigation and rain-fed production are also presented.

4.1 Yield, Precipitation, and Temperature Simulation

Yields and prices for corn and soybean were generated from a simulated distribution. Specifically, yields were simulated from a multivariate empirical (MVE) distribution using the Microsoft Excel Add-in Simetar (Richardson, 2008). Simulating random variables from an empirical distribution avoids imposing a specific distribution on variables while also solving correlation and heteroscedasticity problems among the variables (Richardson, Klose and Gray, 2000). According to Richardson (2008), MVE can be used to establish a correlation between non-normally distributed variables in a simulation model. Disregarding the correlation between stochastic variables could result in either an overstatement or understatement of the variance and means of the simulated variable. Given the fact we are assuming a crop rotation between corn and soybean, it is important to establish a relationship between the yields of each crop.

Correlated distributions of historical corn and soybean yields, harvest time futures prices, seasonal precipitation $(PREC)$, seasonal temperature $(TEMP)$ and the difference in harvest and planting time prices are simulated from a two-step MVE as percent deviations from their means. The percent deviations are sorted from smallest to largest for each variable in the correlation matrix with their corresponding cumulative probabilities. A vector of correlated uniform standard deviations $(CUSD)$, which consists of random numbers generated from the correlation matrix, was then created. These random numbers are correlated just as they are in the correlation matrix. The historical correlation matrix contains ten variables, and the $CUSD$ for each variable is a function of all ten variables. The $CUSD = f\left(NCY, NSY, ICY, ISY, TEMP, PREC, CP, \quad SP, f_s, f_c\right)$, where NCY, NSY, ICY and ISY are rain-fed corn, rain-fed soybean, irrigated corn and irrigated soybean yields, respectively. CP and SP are harvest time futures prices for corn and soybean, respectively. f_s and f_c represent the differences between harvest time futures and planting time futures prices for soybean and corn, respectively.

After creating the CUSDs, stochastic deviates were generated for all variables in the correlation matrix from their corresponding sorted deviates (sd), cumulative probability of distribution, $(f(x))$, and their $CUSDs$. Random variables were then simulated for all the specified variables in the correlation matrix for twenty-five years using their historical means and stochastic deviates as the deterministic and random components, respectively. The procedure was repeated for twenty-five periods based on the assumption that an irrigation reservoir constructed under East Mississippi conditions has a useful life of twenty-five years. Following these procedures, stochastic yields were simulated as:

$$y_{jt} = Mean\ Y_j^d \times \left\lfloor 1 + EMP\left(sd_j, f\left(x\right)_j, CUSD_j\right)\right\rfloor + \tau_j \qquad (5.1)$$

Where y_{jt} is the simulated farm level yield for crop j in time t. $Mean\ Y_j^d$ is the average annual historical detrended county yields, and $Emp\left(sd_j, f\left(x\right)_j, CUSD_j\right)$ generates the stochastic deviates. τ_j is the normally distributed farm level noise. The same specification was used to simulate both irrigated and non-irrigated yields.

Apart from harvest time prices, equation 4.1 without τ_j was used to simulate all the variables in the correlation matrix. For example, precipitation is simulated as $PREC_t' = Mean\ PREC \times \left[1 + EMP\left(sd, f(x), CUSD\right)\right]$, where $Mean\ PREC$ is the average of the historical precipitation data. There is no subscript j on the simulated precipitation because we use the same period of precipitation data for both corn and soybean.

4.2 Estimating Harvest Time and Projected Prices

The product of the stochastic simulated yields and the price of each crop at the time of harvest forms the revenue component for both irrigation and rain-fed productions. Dismukes, Arriola and Coble (2010) noted that crop production revenue variability is dependent on prices, yield and their interactions. Studies such as Coble, Heifner and Zuniga (2003) and Barham et al. (2011) have used different simulation models to generate probability distributions of revenue and returns while establishing a correlation between yields and prices. This study assumes harvest time prices for each crop follow a log normal distribution and that they are correlated with the simulated yields through their respective $CUSD$s. Equation 4.2 is used to simulate harvest time prices.

$$p_{jt} \sim \text{lognormal}(\tilde{x}_j, \sigma_j, CUSD_b) \tag{5.2}$$

$$\sigma_j = \delta_j \times \sqrt{D_j} \tag{5.3}$$

Where σ_j is the historical volatility of crop j. $\tilde{x}_j$ is the FAPRI projected mean baseline price. $CUSD_b$ is correlating simulated harvest time prices to the yields through the futures harvest time prices. δ_j is the standard deviation of natural log differences between nearby futures contracts from January 2016 to May 2017, and D_j is the number of trading days for each crop. The historical volatilities capture how much the projected price might change in the future based on the changes in the recent past. Projected prices are generated as follows:

$$p'_{jt} = \ p_{jt} \times (1 + f_{jt}{}') \tag{5.4}$$

Where p'_{jt} is the projected price, and f'_{jt} is the simulated price difference between harvest and planting time prices. The higher of the randomly generated harvest and projected prices along with the average production history and specified coverage levels are used to estimate guaranteed revenues under crop insurance.

4.2.1 Validation of MVE Simulation Procedure

According to Richardson (2008), comparing the simulated and historical distribution statistics can determine the accuracy of a MVE procedure. The covariance matrix and mean vectors of the simulated distribution should be equal to that of the historical distribution. The null hypothesis of an equal covariance matrix and mean vectors between the simulated distribution and historical distributions were tested by a

Box's M test and a student t-test, respectively. Both tests were conducted at a 95% confidence level.

4.3 Net Returns

The stochastic crop yields and prices were incorporated into enterprise budgets to determine the per-acre net returns for each crop under irrigated and rain-fed production over the twenty-five year period. Per-acre net returns for each crop were specified as $f(p_t, y_{ti}, v_{ti}, r_{ti})$, where p_t is stochastic crop price in time *t* and y_{ti} is the stochastic yield output from the MVE simulation. v_{ti} and r_{ti} are variable and fixed input prices, respectively, while *i* represents either irrigated or rain-fed production. The per-acre net return was then multiplied by the total field size under each production system to obtain the annual whole farm net returns before taxes (equation 4.5).

Assuming a 50-50 crop rotation between corn and soybean, the whole farm returns for either irrigated or rain-fed production were estimated as 50 percent each of the returns from corn and soybean. That is, the whole farm returns for irrigated production are 50 percent each of the total returns from irrigated corn and soybean, and the whole farm return from rain-fed production is 50 percent each of the total returns from rain-fed corn and soybean.

$$\pi_{ti} = 0.5\left[(R_{ti} - F_{ti})\right] \cdot A_i \tag{5.5}$$

$$R_{ti} = 0.5\left[\left((p_{ct} y_{cti}) + \alpha z_{cti}\right) + \left((p_{st} y_{sti}) + \alpha z_{sti}\right)\right] \cdot A_i \tag{5.6}$$

$$F_{ti} = E\ 0.5\left[(\kappa_{cti} + \alpha\rho_{cti}) + (\kappa_{sti} + \alpha\rho_{sti})\right] \cdot A_i \tag{5.7}$$

Whole farm annual returns (π_{ti}) are weighted by 0.5 to account for the fact that it is a function of 50 percent each of the revenue (R_{ti}) and cost (F_{ti}) of corn and soybean productions under either irrigation or rain-fed. The expanded forms of (R_{ti}) and (F_{ti}) are shown in equations 4.6 and 4.7, respectively. The subscript j on the simulated harvest time prices and yields is replaced with c and s for corn and soybean respectively. p_{ct} is the stochastic harvest time corn price in year t, y_{cti} is the MVE simulated stochastic corn yield for either irrigation or rain-fed production. p_{st} and y_{sti} are the harvest time soybean prices and MVE simulated yields, respectively. αz_{cti} and αz_{sti} are per-acre indemnity payments received for corn and soybean insurance, respectively. α is a dummy variable with a value of 1 under crop insurance and 0 with no insurance. Indemnity payments are received only when the respective actual revenues or the product of the stochastic harvest time prices and stochastic yields from a production period fall below that of the estimated guaranteed revenue. The sum of the per-acre variable and fixed input costs for corn and soybean production gave the annual total specified cost on a per-acre basis for corn (κ_{cti}) and soybean (κ_{sti}). $\alpha\rho_{cti}$ and $\alpha\rho_{sti}$ represent the premiums for crop insurance paid under corn and soybean production, respectively.

The total field size of the research farm under consideration is 408 acres, and 17 acres have gone into the construction of an irrigation reservoir. There are 339 acres irrigated annually from the structure of the irrigation technology used (center pivot irrigation system). Therefore, in estimating the whole farm returns for irrigation, the annual per-acre returns from irrigated acres were multiplied by 339 acres and per-acre returns from rain-fed production are multiplied by 52 acres. The sum of these two estimated yields comprise the annual whole farm returns for irrigation before taxes. This was done to account for the fact that the center pivot irrigation system does not irrigate the corners of the field. Instead, 52 acres go unirrigated, although crops are still grown on the corners. Whole farm net returns for rain-fed production are the product of per-acre annual returns for non-irrigated land and total field size of the research farm (408 acres). Note that the total field size for irrigation production on the research farm is 391 acres. This is because 17 acres have gone into construction of the water storage system. The loss of production land to the construction of the irrigation reservoir is the opportunity cost for choosing higher and more consistent yields and profits under irrigated agriculture.

The ratio of storage reservoir surface acres to irrigated area on the research farm is about 1:20. We use this ratio as representative of the study area to estimate the returns for investing in a storage reservoir to irrigate 80- and 160-acre fields. For example, an irrigated area of 160 acres requires an 8-acre storage reservoir using a similar ratio. The estimated ratios are for the surface area of the pond, the depth of the pond is assumed to be 25 feet as the base pond depth. The mentioned irrigated field sizes are used to reflect the range of field sizes in the study area. Table 4.1 shows the number of acres that are irrigated on each field based on the structure of the irrigation technology.

Table 4.1 Land Available for Irrigation Using a Center Pivot Irrigation System in Combination with On Farm Water Storage system.

Field size	Irrigated acres	Non-irrigated acres
80	66	10
160	133	19
408	339	52

4.4 Taxable Returns

An accelerated depreciation technique was used to depreciate the total investment cost for five years. Accelerated depreciation is when the cost of an asset is recovered at a faster rate than it should take in reality (Review of Business Taxation, 1999). There are several different forms of accelerated deprecations. The method used in this study is a simple and commonly used method known as the *American system.* This method is very similar to straight line depreciation but with a shortened useful life. For example, if an investor pays $50,000 for an asset with an assumed life span of ten years, $5,000 would be deducted annually over the ten year period if depreciated equally. Accelerating the depreciating rate for four years will mean deducting $12,500 per year for the first four years with no deduction in subsequent years.

Accelerated depreciation allows producers to defer a portion of their taxes in the early years of using a piece of farm equipment. Deferred taxes provide producers with an additional source of financing to purchase new equipment, market goods, and possibly grow the farm businesses by reducing their tax liability during the first few years after an investment is made.

As mentioned above, this study depreciates the cost of irrigation investment with a shortened useful life of five years and assumes a salvage value of zero. Hence, the taxable returns from the irrigation investment are obtained by subtracting the depreciated amount from the whole farm net returns before taxes for the first five years as shown in equation 4.8.

$$\pi'_{ti} = \pi_{ti} - dep_5 \tag{5.8}$$

Where π'_{ti} the taxable net returns in year t. dep_5 is depreciation over a five-year period, and π_{ti} are the whole farm annual returns before taxes for either irrigation or rain-fed production from equation 4.5. Money received after the depreciation period is still accounted for as gains.

The residual amount or salvage value is the expected value of an asset at the end of its useful life. Since irrigation equipment is usually still put to use or parts put up for sale after their useful life (Lamm O'brien and Rogers, 2005), a zero salvage value assumption may seem incorrect. But, this is a common approach to avoid incorrect estimation of the value of an asset past its useful life. Secondly, this assumption has no major impact on the economic analysis if an asset is depreciated over a long period of time with typical discount rates (Lamm O'brien and Rogers, 2005).

4.5 Cash Flows

The amount paid in taxes is obtained by multiplying the estimates from equation 4.8 by a tax rate. In this study, a tax rate of 30 percent was assumed. Annual cash flows to be discounted were estimated by subtracting the amount paid in taxes from the total returns before taxes. This is shown in equation 4.9 as:

$$CF_{ti} = \pi_{ti} - \left(\pi'_{ti} \cdot \phi\right), \tag{5.9}$$

where CF_{ti} is the annual cash flows after taxes, the product of π'_{ti} and ϕ gives the amount paid in taxes with ϕ as the tax rate. π'_{ti} is the taxable net returns from equation 4.8, and π_{ti} is the whole farm annual returns.

4.6 Net Present Value

After identifying all benefits and costs of a project in monetary values, it is important to convert them to present value to account for time preferences (Barbier and Hanley, 2009). Three commonly used alternative criteria for discounting over time, to determine whether an investment will be worthwhile, are the net present value, internal rate of returns and the benefit cost ratio. By definition, the net present value is the sum of present values of a project's benefits minus the sum of the present value of its cost. The internal rate of return is defined as the interest rate that will generate a net present value of zero. The benefit-cost ratio of an investment is the ratio of its present value benefits to its present value costs (Zerbe and Bellas, 2006). These criteria sometimes give different rankings when choosing among investments (Osborne, 2010).

According to Kay, Edward and Duffy (2008), the net present value approach is the most preferred among the alternatives due to its ability to account for the time value of money as well as the stream of cash flows over the entire investment period. Generally, all calculated internal rate of returns and benefit cost ratio are accompanied by a net present value (Zerbe and Bellas, 2006). The net present value has been widely used to evaluate the economic value of water storage and irrigation systems (e.g. Falconer et. al., 2015; Boyer et al., 2014; Popp et al., 2003; Williams et al., 1996; Boggess and Amerling, 1983; Boggess et al., 1983).

We chose to employ the net present value approach to analyze the returns of irrigating from an irrigation reservoir compared to rain-fed production. The net present value of the system is calculated from equation 4.10. The initial investment cost is inv, λ is the discount rate, and L is the assumed useful life of the investment. CF_{ti} represents the cash flows after taxes in time t for scenario i.

$$NPV = -inv + \sum_{t=1}^{L} \frac{CF_{ti}}{\left(1+\lambda\right)^{t}} \tag{5.10}$$

Under irrigated production, a positive net present value (NPV) from equation 11 means the returns for making the irrigation investment are higher than the cost involved. In other words, the returns of the investment meet and exceed the cost. However, we consider irrigation not worthwhile when positive net present values are less than that of rain-fed production. A negative NPV means the cost of investment is higher than returns. The initial investment cost is zero for rain-fed production, but the estimated NPV provides a baseline to which the irrigation system investment can be compared. As previously stated, the useful life of the irrigation reservoir is twenty-five years and is consistent with the assumed life span for the irrigation technology.

The discount rate is the rate used to determine the present value of the future cash flows of both productions. The net present value estimate for any investment can be uncertain due to its dependence on uncertain future cash flows. One way to address this uncertainty is to vary the discount rates used in estimating the net present value. Besides, the discount rate of any investment varies from person to person because it is equivalent to the rate of the equity capital used in each enterprise that returns its most favorable alternative use (Falconer, Lewis and Krutz, 2015). For this reason, the discount rate was varied over five different rates (2%, 4%, 6%, 8%, and 10%) in a sensitivity analysis. We estimated the net present value under two scenarios. First, we assume the irrigation system is purchased up-front. That is, the cost of investment is paid outright before the system is put in use. Secondly, we assume the investment is financed through a series of annual payments over a ten-year period. We use a loan interest rate of 5% which is toward the upper range of prevailing interest rates.

4.7 Risk Ranking

Probability distributions of net present value (NPV) estimates for both irrigated and rain-fed prodFuction are represented in cumulative distributive functions (CDFs) to determine the best scenario among the two. For each irrigated field size, we created four different charts. Each chart is at a specific discount rate and has ten CDFs. Specifically, each chart has ten CDFs comparing the NPV distributions of irrigated and rain-fed production without crop insurance and with crop insurance at four different crop insurance coverage levels (70%, 75%, 80%, and 85%). The cumulative distributions of the NPVs are compared under first-degree stochastic dominance $(\mathrm{FSD}: F(N) - G(N) \geq 0 \ \forall \ N)$ and second-degree stochastic dominance $(\mathrm{SSD}: \int_b^a \left[G(N) - F(N)\right] dN \geq 0 \forall N)$, where $F(N)$ and $G(N)$ are cumulative distributions of the simulated NPV. Here, $F(N)$ is preferred to $G(N)$ under both FSD and SSD.

Stochastic efficiency of the cumulative distributions of the NPV was analyzed with respect to a utility function. SERF was used to rank the NPV distributions over a range of relative risk aversion coefficients. The SERF analysis specifies a decision maker's utility as a function of the NPV distributions and a relative risk aversion coefficient (r_r), $U(N_i, r_r)$, where N_i is the simulated NPV distribution for each scenario with or without crop insurance over the twenty-five year period. A negative exponential utility function $(U(N_i) = -\exp^{(-r_a * N_i)})$ was assumed for a risk averse decision maker. The specified utility function allows for only risk aversion, and it exhibits a constant absolute risk aversion (CARA). That is $r_a(N_i) = -\dfrac{u''(N_i)}{u'(N_i)}$, as explained by Pratt (1964). Due to the stochastic nature of the key output variable, NPV, we can expect the absolute risk aversion to change over the multiple years. The absolute risk aversion coefficient, $r_a(N_i)$ is converted to relative risk aversion coefficient, $r_r(N_i)$ by simply multiplying the $r_a(N_i)$ by the NPV at any given level. The assumption here is that the relative risk aversion coefficient remains approximately constant when the NPV changes.

Following Anderson and Dillion (1992), a range of relative risk aversion coefficients from 0 to 4 was used. Anderson and Dillion (1992) noted that an individual's degree of risk aversion can be characterized by a standard relative risk aversion coefficient (r_r or $RRAC$) which ranges from 0 as risk neutral to 4 as extremely risk averse (Table 4.2). This study assumes the wealth of a crop producer is equivalent to the obtained NPV. This assumption is made because the scale of risk aversion applies to wealth and not the stochastic net present values. To allow for an easy interpretation of the results in monetary terms, we convert the utility associated with the wealth into certainty equivalent by taking the inverse of the utility function, $CE(W_i, r_r) = U^{-1}(W_i, r_r)$, where W_i is the same as the simulated net present values mentioned previously.

As explained in the previous section, SERF estimates a certainty equivalent over the range of risk aversion coefficients (RAC) rather than selecting a particular RAC. The ability to evaluate the certainty equivalent at various RACs makes it possible to determine a risk averse decision maker's preferred choice at and within the lower and upper risk aversion bounds. At each RAC, the alternative with the highest certainty equivalent is considered as the preferred option for a risk averse decision maker. Using two alternatives as an example, $F(N)$ is preferred to $G(N)$ at RAC_k if $CE_{Fk} > CE_{Gk}$, and $F(N)$ is indifferent to $G(N)$ at RAC_k if $CE_{Fk} = CE_{Gk}$. Where CE_{Fk} and CE_{Gk} are certainty equivalents for the two alternatives at a specific $RAC\ k$.

Table 4.2 Characterization for relative risk aversion coefficients.

RRAC	Characterization
0	Risk Neutral
0.5	Hardly risk averse
1	Somewhat risk averse
2.0	Rather risk averse
3.0	Very risk averse
4.0	Extreme risk averse

Source: Anderson and Dillion, (1992)

CHAPTER V

RESULTS

Chapter five presents the results of this study. The reported results include summary statistics of simulated net present value of irrigating from an irrigation reservoir and rain-fed production. The complete distribution of the net present values are reported in cumulative distribution functions, and the preferred options based on a decision maker's relative risk aversion levels are shown in stochastic efficiency with respect to a utility function (SERF charts). This section starts with the results of a validation test that confirms the appropriateness of the simulated variables used in the analysis to achieve the reported findings.

5.1 Validation Test for MVE Simulation

5.1.1 Correlation Test between Actual and Simulated Variables

The correlation matrix of the actual and historical data is shown in Table 5.1. Student t-test values that confirm the similarity in correlation between historical and simulated variables are shown in Table 5.2. At a 99.8% confidence level, all test values were less than the critical value (3.26). This shows that all of the stochastic multivariate empirical (MVE) simulated variables are statistically significant. We can therefore conclude that the correlation coefficient implicit in the randomly generated variables are statistically equal or correlated (Richardson, 2008). This matrix was used for generating each variable's correlated uniform standard deviates (CUSD), simulations, and analysis.

Though statistically significant in the correlation coefficients test, it should be noted that the harvest time prices for both corn (CP) and soybean (SP) in Table 5.2 are not simulated from MVE. They are shown here to ensure that the historical and simulated data matrices are complete and equal in size to avoid errors in the test for correlation coefficients. CP and SP were also included so that the simulated values are correlated with other variables in the correlated matrix. As shown earlier, SP and CP are simulated from a log normal distribution based on historical volatilities.

Table 5.1 Correlation matrix of actual data.

	SP	CP	NSY	NCY	ICY	ISY	TEMP	PREC	f_s	f_c
SP	1	0.93	0.19	-0.28	0.40	0.11	0.08	0.21	-0.28	-0.34
CP		1	0.07	-0.39	0.33	0.06	0.28	0.02	-0.23	-0.51
NSY			1	0.62	0.14	0.55	-0.59	0.50	0.10	0.37
NCY				1	-0.14	0.26	-0.52	0.35	0.22	0.46
ICY					1	0.33	-0.18	-0.12	-0.01	0.04
ISY						1	-0.45	0.28	0.26	0.38
TEMP							1	-0.48	-0.27	-0.52
PREC								1	-0.10	0.19
f_s									1	0.69
f_c										1

NSY= Non-irrigated soybean yield, NCY=Non-irrigated corn yield, ICY=Irrigated corn yield, ISY=Irrigated soybean yield. f_s and f_c are the differences in harvest and planting time futures prices for soybean and corn respectively.

Table 5.2 T-value matrix to test for similar correlation.

	SP	CP	NSY	NCY	ICY	ISY	TEMP	PREC	f_s	f_c
SP		0.67	0.75	0.41	0.35	0.20	0.99	1.50	1.98	0.17
CP			0.54	0.50	0.86	0.11	0.40	1.26	1.41	0.87
NSY				0.54	0.47	0.02	0.94	0.86	0.49	0.96
NCY					0.67	0.34	0.82	0.63	1.47	0.15
ICY						0.06	1.19	0.76	1.59	1.96
ISY							0.71	0.69	0.67	0.29
TEMP								1.37	0.27	0.38
PREC									1.77	1.12
f_s										0.82
f_c										

NB: Critical value 3.26, Confidence level 95%

5.1.2 Verification Test for MVE distribution

Table 5.3 reports the results for testing the MVE simulated parameters against their historical means. Findings show that the mean of the individual parameters simulated are not different from their corresponding historical means. As reported, the null hypothesis of equal means is not rejected for all simulated parameters. On the other hand, the Boxes-M Test which tests the equality of the covariance matrix of the historical and randomly generated variable rejected the null hypothesis of an equal covariance matrix at a 95% confidence level. The difference in covariance matrix was expected due to an increase in the variance of the simulated yields resulting from the additional noise added to the simulated county-level yield to generate farm-level yields. The student test rejected the null hypothesis of equal standard deviation of the yields for the same reason (Table 5.4).

Table 5.3 Student test results for simulated MVE parameters against their historical means.

	Given Value	Test Value	Critical Value	P-value	Hypothesis Test
NSY	41.7	0.03	2.24	0.98	Fail to Reject that mean is equal to 41.7
ISY	51.5	-0.03	2.24	0.98	Fail to Reject that mean is equal to 51.5
NCY	140.2	-0.01	2.24	0.98	Fail to Reject that mean is equal to 140.2
ICY	176	-0.05	2.24	0.96	Fail to Reject that mean is equal to 176
TEMP	23.9	-0.02	2.24	0.84	Fail to Reject that mean is equal to 23.90
PREC	22.8	-0.19	2.2	0.85	Fail to Reject that mean is equal to 22.8
f_s	0.03	-0.11	2.24	0.91	Fail to Reject that mean is equal to 0.03
f_c	0.096	-0.001	2.24	0.91	Fail to Reject that mean is equal to 0.096

NSY= Non-irrigated soybean yield, NCY=Non-irrigated corn yield, ICY=Irrigated corn yield, ISY=Irrigated soybean yield. f_s and f_c are the differences in harvest and planting time futures prices for soybean and corn, respectively.

Table 5.4 Chi-Square Test results for simulated MVE parameters against their historical standard deviation.

	Given Value	Test Value	Critical Value	P-value	Hypothesis Test
NSY	6.45	9823	LB: 913 UB: 1,088	0.00	Reject that SD is equal to 6.45
ISY	5.03	2420	LB: 913 UB: 1,088	0.00	Reject that SD is equal to 5.03
NCY	22.3	6973	LB: 913 UB: 1,088	0.00	Reject that SD is equal to 22.3
ICY	18.3	5621	LB: 913 UB: 1,088	0.00	Reject that SD is equal to 18.3
TEMP	0.77	984	LB: 913 UB: 1,088	0.69	Fail to Reject that SD is equal to 0.77
PREC	4.94	958	LB: 913 UB: 1,088	0.36	Fail to Reject that SD is equal to 4.94
f_s	0.17	1010	LB: 913 UB: 1,088	0.78	Fail to Reject that SD is equal to 0.17
f_c	0.19	993	LB: 913 UB: 1,088	0.91	Fail to Reject that SD is equal to 0.19

NSY= Non-irrigated soybean yield, NCY=Non-irrigated corn yield, ICY=Irrigated corn yield, ISY=Irrigated soybean yield. f_s and f_c are the differences in harvest and planting time futures prices for soybean and corn respectively. LB=Lower bound, UB= Upper bound. SD= Standard deviation.

5.2 Summary Statistics of Net Present Value

As expected, the simulated net present value for both irrigated and rain-fed production increases as the discount rate decreases. This pattern is observed for all field sizes under consideration. The net present values vary significantly based on field size and discount rates with the lowest and highest per-acre estimates not surprisingly observed under 80 acres and 160 acres, respectively. Simulation results of the twenty-five years net present value analysis indicates positive net present values for rain-fed production for all specified discount rates (2%, 4%, 6%, 8% and 10%), while irrigated production occasionally yields negative net present values, especially at high discount rates.

Comparatively, the simulated net present value for irrigating from an irrigation reservoir at the various field sizes and discount rates are less than that of rain-fed production. We observe that as the discount rate increases, the net present value of rain-fed production decreases at a lower rate compared to irrigated production. In other words, the net present values of rain-fed production are significantly higher than irrigated production at higher discount rates when the irrigation investment costs are paid up-front. Conversely, the net present value of irrigated production increases at a higher rate than rain-fed production, as discount rate decreases. However, discount rates would have to be below 2% before net present value of irrigated production will be significantly higher than that of rain-fed production when construction costs are paid up-front.

5.2.1. Up-Front Payment for Irrigation Investment

Tables 5.5, 5.6 and 5.7 report the mean, standard deviation, minimum and maximum values of net present value per acre with and without revenue protection crop insurance for both irrigated and rain-fed production on 80-acre, 160-acre and 408-acre field sizes, respectively. The net present value estimates in Tables 5.5, 5.6, and 5.7 assume the cost of the irrigation investment is paid up-front. Results from Table 5.5 show that without crop insurance, irrigated production had an average net present value of \$187/acre at a 2% discount rate. The mentioned per-acre net present value is the only positive net present value simulated without crop insurance, which means investing in an

OFWS system for irrigation is not worth the cost for an 80-acre field size in the study area when discount rates are at 4%, 6%, 8% and 10%. The lowest simulated net present value without crop insurance is -$646/acre, which is at a 10% discount rate for irrigated production on an 80-acre field size.

An increase in field size increases the simulated whole farm returns, cash flows and, as expected, the net present values. Unlike the 80-acre field size, which had a positive net present value for irrigation at only a 2% discount rate (without crop insurance), the per-acre net present value for a 160-acre field size is positive for all discount rates (without crop insurance) except for 8% and 10% (Table 5.6). Specifically, with no crop insurance, irrigated production on a 160-acre farm had a positive net present value at 2% ($683/acre), 4% ($376/acre), 6% ($151/acre), and negative net present values of $18/acre and $146/acre at 8% and 10% discount rates, respectively. Investing in an irrigation reservoir results in a positive net present value on the 408-acre field size at discount rates of 2%, 4% and 6% without crop insurance, with net present values of $558/acre, $248/acre and $22/acre, respectively (Table 5.7). Similar to the 160-acre field size, the returns of irrigation are not enough to offset the cost of irrigation investment on the 408-acre field size at 8% and 10% discount rates.

Our net present value estimates for the 160-acre field size are lower than that of Falconer, Lewis and Krutz (2015), who showed that the net present value of irrigating from an OFWS (with a tailwater recovery system) and a center pivot irrigation system on a 160-acre field size is higher than that of rain-fed production, even at a 5% discount rate. Our findings indicate that the discount rate should be as low as 2% before the net present value of irrigation on 160 acres becomes higher than that of rain-fed production. The difference in the two estimates is, however, not surprising as producers in their study area enjoy cost assistance advantages from the USDA – Natural Resources Conservation Service (NRCS) for constructing OFWS. The estimates used by Falconer, Lewis and Krutz (2015) included NRCS financial assistance of $164,868.80.

Protecting revenues under crop insurance makes both production scenarios more attractive and significantly reduces the variability in net present value of both scenarios at all coverage levels. But, the reduction in net present value variability under irrigation production is higher than that of rain-fed production. This shows that crop insurance is complementing irrigation as a risk management tool. In other words, the combination of irrigation and crop insurance significantly reduces the risk of obtaining lower returns relative to the use of only irrigation or depending on rain-fed production without crop insurance. From the summary statistic tables, this is shown in a reduced standard deviation and reduced range of minimum and maximum values of the simulated net present values for all field sizes and discount rates.

The reduction in variability of net present value increases as the coverage level increases from 70%. For instance, Table 5.5 indicates that at a 2% discount rate, the net present value for an 80-acre irrigated field increases from $187/acre without crop insurance to $584/acre, $672/acre, $748/acre and $1,248/acre at 70%, 75%, 80%, and 85% coverage levels, respectively. In the same respective order, the standard deviation decreases from $595/acre without crop insurance to $472/acre, $451/acre, $429/acre and $418/acre with increasing levels of insurance coverage. The range of minimum and maximum present values decrease accordingly. A similar trend is observed under rain-fed production for all field sizes with a higher net present value and standard deviation as reported in Table 5.5.

Though crop insurance significantly reduces the variability and increases net present values, investing in an irrigation reservoir with up-front payments is not worthwhile, as it generates lower net present values relative to rain-fed production at high discount rates, regardless of crop insurance coverage levels. For example, on a 160-acre irrigated field size, an increase in discount rate from 2% to 4% reduces the net present value of $683/acre without crop insurance to $376/acre. Including crop insurance at 70%, 75%, 80%, and 85% coverage levels increases the net present value to $696/acre, $768/acre $831/acre and $864/acre, respectively, but these values are lower than net present values under rain-fed production. This means that though there is an improvement in net present value and the returns for irrigation accumulate enough to offset the cost of investment, producers will be better off depending on rain-fed production given the higher net present value estimates. On the whole, protecting revenues under crop insurance with up-front payments for the irrigation investment generates positive net present value for all specified coverage levels, field sizes and discount rates. The net present values for irrigation are lower than that of rain-fed production at all discount rates (only on 80 acres) and at 4%, 6%, 8% and 10% discount rates (on 160- and 408- acre fields).

Based on average net present value estimates, we found that interest rates as low as 2% are needed for irrigation to be a better option or have net present value estimates similar to that of rain-fed production with or without crop insurance. However, this finding is applicable to only a 160-acre representative field size. The cost of irrigation technology significantly reduces the profitability of irrigation on smaller field sizes, even at lower interest rates. This finding is in accordance with Dalton, Porter, and Window (2004) who reported that capital intensive irrigation technologies reduce the profitability of irrigation on small field sizes. Given that we used the same reservoir-to-field size ratio for all field sizes, we can conclude that the dissimilarity between the per acre net present values on the various field sizes is significantly influenced by the cost of center pivot irrigation technology. It is assumed that a one half-mile center pivot irrigation system would be used for both 160- and 80-acre field sizes, with the 80-acre field size only making a half circle. Hence, the cost of irrigated production on the 80-acre is higher when compared to 160 acres, despite the cost of constructing reservoirs that are proportionally the same. The fact that the per acre net present value of a 160-acre field size is higher than that of the base field size shows that the three center pivot irrigation systems are more than what is needed for a 339-acre irrigated area. In other words, a more efficient and less expensive irrigation technology is needed to significantly increase the profitability of irrigating from an OFWS, especially for producers operating on smaller field sizes.

5.2.2. Financing Irrigation Investment

With the assumption that the irrigation investment is financed over a ten-year period, we estimated the net present value for irrigation on a 160-acre field size to determine how it compared to making an up-front payment based on the prevailing interest rates. Table 5.8 reports the summary statistics for the net present value on a 160-acre field size when the irrigation investment is financed. Contrary to the net present value estimates under up-front payment on a 160-acre field (Table 5.6), irrigated production had positive net present values for irrigation (with and without crop insurance) at all discount rates when the system is financed over the specified years. The positive net present values obtained at 8% and 10% discount rates (without crop insurance) through financing the investment compares to -$18/acre and -$146/acre, respectively, when payment is made up-front. This shows that at high interest rates, the freedom of making reduced annual payments through financing the investment generated higher returns relative to making an up-front payment. Avoiding a down payment will give investors an extra source of funds to invest in other aspects of the farm business that will increase the whole farm returns at high interest rates.

As stated previously, positive net present value is obtained for financing the system at all discount rates on a 160-acre field size both with and without crop insurance. However, the net present value estimates for financing are similar to that of making an up-front payment in terms of generating a net present value that falls above that of rain-fed production or generating net present values that make irrigation worthwhile. Making the irrigation investment with a series of annual payments over ten years is worthwhile at the 2% discount, and this is more evident when revenues are protected at an 85% coverage level. At the 4% discount rate, financing the investment and protecting revenues at the 85% coverage level on a 160-acre field size had a net present value of $951/acre compared to $864/acre for making an up-front payment. The stated net present values at 4% discount rates for making the irrigation investment compares to $917/acre for dryland production. This indicates that financing the investment makes irrigation a better option than rain-fed production, but producers will be better off depending on rainfall if an up-front payment is to be made at the 4% interest rate.

Annual installment payments for the irrigation investment increases the returns for irrigation and generates a positive net present value at all discount rates, but irrigation is considered not worthwhile at 6%, 8% and 10% discount rates as the net present values are lower than rain-fed production. As shown in Table 5.8, financing the investment makes irrigation a better option than rain-fed production at the 4% interest rate, but to observe this, financing must be complimented with crop insurance at coverage levels higher than 80%. Based on the reported estimates at the specified discount rates, we found that financing is the best option for making such an irrigation investment. It should be noted, however, that it will be better to make an up-front payment if the interest rates on loans are high. This explains why the average net present value for up-front payment at the 2% discount rate (Table 5.6) is higher than that of financing. Given that the current prevailing interest rate on a ten-year loan ranges from 4% to 5%, financing the investment is a better option than an up-front payment of the investment.

5.3 Sensitivity Analysis

A sensitivity analysis was conducted showing that net present values are very sensitive to variations in the initial cost of constructing an irrigation reservoir. We conducted a sensitivity analysis using ±20% and ±40% of the cost of constructing an irrigation reservoir. Though the irrigation investment includes both the irrigation technology and reservoir, only the cost of reservoir is varied because potential financial assistance from the National Resources Conservation Serve (NRCS) for eligible irrigating farmers would be for the conservation advantages of the reservoir. The NRCS seeks to achieve its goals of Mississippi River Basin Healthy Watersheds Initiative (MRBI) by providing assistance to farmers to voluntarily implement conservation practices (MRBI

Progress Report, 2016). Farmers in the delta region of Mississippi have been receiving financial assistance from NRCS to construct tailwater recovery and OFWS systems.

Generally, a decrease (increase) in the initial cost of the irrigation reservoir increases (decreases) the net present value of irrigation. Using a 20% and 40% reduction in reservoir cost, we found that the net present value for irrigation on an 80-acre field size still falls below that of rain-fed production. Table 5.5 shows that investing in an irrigation reservoir on an 80-acre field size had a positive net present value only at a 2% discount rate with or without crop insurance. Sensitivity analysis indicates that a 20% decrease in the reservoir cost can generate a positive net present value at the 4% discount rate. However, the increase in net present value is not adequate to make irrigation a better option over rain-fed production. With a 20% and 40% decrease in reservoir cost, the net present value of irrigation on a 160-acre field becomes significantly higher than that of rain-fed production when discount rates are at 2%. At a 4% discount rate, the reduction in reservoir cost should be 40% or above to make irrigation worthwhile on a 160-acre and 408-acre field size when the cost of investment is recovered through an up-front payment, while financing the system makes irrigation a better option with a 20% reduction in reservoir cost on a 160-acre field.

Significant improvement is obtained in net represent values for irrigated production at all discount rates due to a reduction in reservoir cost, but a 20% and 40% reduction at the specified discount rates are not adequate to make such an investment worthwhile on an 80-acre field. With up-front payments, the stated percentage reduction in reservoir cost is not enough to make irrigation worthwhile on 160 acres at discount rates above 6%, but financing with a 40% cost reduction makes irrigation attractive even at a 10% discount rate if revenues are protected at high coverage levels. This is an indication that the reduction in the construction costs of irrigation reservoirs through cost assistance opportunities in East Mississippi will significantly increase the profitability of irrigated production. However, the percentage reduction in cost should be much more than 40% when discount rates are high. Using a discount rate of 8%, Popp et al. (2003) noted that cost share opportunities of about 75% are needed to significantly make OFWS profitable for producers. Tables A1 –A4 in Appendix A report the changes in net present value for irrigated production with and without crop insurance.

Table 5.5 NPV for 80 acres with up-front payment for irrigation investment

		2%		4%		6%		8%		10%	
		I	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	187	648	(122)	518	(347)	424	(517)	353	(646)	300
	SD($)	595	1,514	500	1,223	434	1,011	387	854	352	735
	Min($)	(1,540)	(3,546)	(1,537)	(2,788)	(1,723)	(2,245)	(1,835)	(1,926)	(1,902)	(1,681)
	Max($)	2,327	5,069	1,600	4,141	1,063	3,453	658	2,931	349	2,529
70%	Mean($)	584	1,092	198	873	(85)	715	(296)	597	(458)	507
	SD($)	472	1,006	397	814	346	674	309	571	281	492
	Min($)	(660)	(708)	(883)	(604)	(1,038)	(517)	(1,151)	(446)	(1,268)	(388)
	Max($)	2,525	4,976	1,756	4,068	1,186	3,392	756	2,878	451	2,482
75%	Mean($)	672	1,147	270	918	(25)	751	(246)	627	(415)	533
	SD($)	451	941	379	761	330	631	295	534	269	461
	Min($)	(488)	(524)	(739)	(455)	(915)	(395)	(1,050)	(344)	(1,177)	(301)
	Max($)	2,583	4,931	1,808	4,030	1,233	3,359	798	2,850	491	2,456
80%	Mean($)	748	1,172	331	938	26	767	(296)	641	(377)	545
	SD($)	429	878	361	711	314	589	309	499	256	431
	Min($)	(344)	(394)	(596)	(350)	(793)	(308)	(1,151)	(271)	(1,090)	(239)
	Max($)	2,610	4,843	1,831	3,957	1,253	3,298	756	2,797	519	2,410
85%	Mean($)	1,286	1,145	364	917	53	750	(179)	626	(357)	533
	SD($)	418	818	343	662	298	549	267	465	243	401
	Min($)	197	(309)	(473)	(280)	(707)	(249)	(884)	(221)	(1,019)	(196)
	Max($)	3,109	4,713	1,809	3,849	1,235	3,206	802	2,717	520	2,340

NI=No Insurance, I=Irrigation production, R=Rain-fed production, 70%, 75%, 80% and 85% are coverage levels

Table 5.6 NPV for 160 acres with up-front payment for irrigation investment

		2%		4%		6%		8%		10%	
		I	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	683	648	376	518	151	424	(18)	353	(146)	300
	SD($)	580	1,514	484	1,223	418	1,011	371	854	336	735
	Min($)	(1,050)	(3,546)	(1,018)	(2,788)	(1,204)	(2,245)	(1,317)	(1,926)	(1,383)	(1,681)
	Max($)	2,784	5,069	2,062	4,141	1,528	3,453	1,127	2,931	820	2,529
70%	Mean($)	1,081	1,092	696	873	415	715	204	597	43	507
	SD($)	458	1,006	383	814	331	674	294	571	266	492
	Min($)	(130)	(708)	(354)	(604)	(509)	(517)	(628)	(446)	(745)	(388)
	Max($)	2,993	4,976	2,228	4,068	1,660	3,392	1,233	2,878	922	2,482
75%	Mean($)	1,170	1,147	768	918	474	751	255	627	87	533
	SD($)	437	941	365	761	315	631	280	534	254	461
	Min($)	42	(524)	(210)	(455)	(387)	(395)	(526)	(344)	(653)	(301)
	Max($)	3,051	4,931	2,279	4,030	1,706	3,359	1,273	2,850	963	2,456
80%	Mean($)	1,247	1,172	831	938	526	767	306	641	125	545
	SD($)	415	878	346	711	299	589	240	499	241	431
	Min($)	189	(394)	(67)	(350)	(265)	(308)	(338)	(271)	(565)	(239)
	Max($)	3,078	4,843	2,302	3,957	1,726	3,298	1,216	2,797	992	2,410
85%	Mean($)	1,288	1,145	864	917	554	750	322	626	146	533
	SD($)	395	818	329	662	284	549	252	465	228	401
	Min($)	278	(309)	58	(280)	(178)	(249)	(356)	(221)	(493)	(196)
	Max($)	3,054	4,713	1,809	3,849	1,711	3,206	1,280	2,717	995	2,340

NI=No Insurance, I=Irrigation production, R=Rain-fed production, 70%, 75%, 80% and 85% are coverage levels

Table 5.7 NPV for 408 acres with up-front payment for irrigation investment

		2%		4%		6%		8%		10%	
		I	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	558	648	248	518	22	424	(148)	353	(278)	300
	SD($)	590	1,514	494	1,223	427	1,011	380	854	344	735
	Min($)	(1,182)	(3,546)	(1,156)	(2,788)	(1,342)	(2,245)	(1,456)	(1,926)	(1,523)	(1,681)
	Max($)	2,712	5,069	1,980	4,141	1,439	3,453	1,032	2,931	721	2,529
70%	Mean($)	959	1,092	571	873	287	715	75	597	(87)	507
	SD($)	467	1,006	391	814	338	674	301	571	273	492
	Min($)	(273)	(708)	(498)	(604)	(654)	(517)	(767)	(446)	(885)	(388)
	Max($)	2,917	4,976	2,143	4,068	1,569	3,392	1,136	2,878	811	2,482
75%	Mean($)	1,048	1,147	644	918	347	751	126	627	(43)	533
	SD($)	445	941	373	761	323	631	287	534	261	461
	Min($)	(100)	(524)	(352)	(455)	(530)	(395)	(665)	(344)	(793)	(301)
	Max($)	2,975	4,931	2,194	4,030	1,615	3,359	1,177	2,850	852	2,456
80%	Mean($)	1,125	1,172	706	938	399	767	170	641	(5)	545
	SD($)	423	878	354	711	306	589	273	499	247	431
	Min($)	45	(394)	(208)	(350)	(407)	(308)	(569)	(271)	(705)	(239)
	Max($)	3,001	4,843	2,216	3,957	1,634	3,298	1,195	2,797	882	2,410
85%	Mean($)	1,166	1,145	739	917	427	750	194	626	16	533
	SD($)	403	818	336	662	291	549	259	465	235	401
	Min($)	140	(309)	(85)	(280)	(320)	(249)	(499)	(221)	(634)	(196)
	Max($)	2,972	4,713	2,193	3,849	1,615	3,206	1,179	2,717	886	2,340

NI=No Insurance, I=Irrigation production, R=Rain-fed production, 70%, 75%, 80% and 85% are coverage levels

Table 5.8 NPV for 160 acres with financing of irrigation investment

		2%		4%		6%		8%		10%	
		I	**R**	**I**	**R**	**I**	**R**	**I**	**R**	**I**	**R**
NI	Mean($)	661	648	445	518	299	424	203	353	131	300
	SD($)	607	1,514	511	1,223	444	1,011	408	854	360	735
	Min($)	(1,110)	(3,546)	(1,053)	(2,788)	(1,149)	(2,245)	(1,024)	(1,926)	(1,182)	(1,681)
	Max($)	2,842	5,069	2,201	4,141	1,739	3,453	1,399	2,931	1,147	2,529
70%	Mean($)	1,069	1,092	774	873	570	715	427	597	326	507
	SD($)	484	1,006	408	814	356	674	318	571	289	492
	Min($)	(229)	(708)	(354)	(604)	(425)	(517)	(493)	(446)	(542)	(388)
	Max($)	3,041	4,976	2,358	4,068	1,863	3,392	1,497	2,878	1,242	2,482
75%	Mean($)	1,162	1,147	850	918	633	751	480	627	371	533
	SD($)	462	941	390	761	340	631	303	534	276	461
	Min($)	(52)	(524)	(206)	(455)	(299)	(395)	(387)	(344)	(447)	(301)
	Max($)	3,107	4,931	2,417	4,030	1,916	3,359	1,545	2,850	1,283	2,456
80%	Mean($)	1,243	1,172	915	938	688	767	527	641	411	545
	SD($)	439	878	370	711	323	589	288	499	262	431
	Min($)	93	(394)	(58)	(350)	(173)	(308)	(285)	(271)	(355)	(239)
	Max($)	3,135	4,843	2,441	3,957	1,937	3,298	1,565	2,797	1,315	2,410
85%	Mean($)	1,286	1,145	951	917	717	750	552	626	433	533
	SD($)	418	818	352	662	307	549	274	465	249	401
	Min($)	197	(309)	65	(280)	(80)	(249)	(204)	(221)	(280)	(196)
	Max($)	3,109	4,713	2,420	3,849	1,920	3,206	1,551	2,717	1,318	2,340

NI=No Insurance, I=Irrigation production, R=Rain-fed production, 70%, 75%, 80% and 85% are coverage levels

5.4 Risk Ranking Results

The complete probability distribution of the simulated net present value for both rain-fed and irrigated production were represented in a cumulative distribution function (CDF) to determine the best option among the two scenarios both without crop insurance and with crop insurance at the four coverage levels. For each field size, we created five different CDF charts, each with ten CDFs at a specific discount rate. Each chart compares ten CDFs representing five net present value distributions of irrigated and five net present value distributions of rain-fed production at a specific discount rate. For a given field size, the difference among the various CDF and SERF charts are the prevailing discount rates. The CDF and SERF charts for 80- and 160-acre field sizes at two discount rates are used as examples to show the pattern of net present value distribution for the field sizes. Refer to Appendices B and C for the remaining graphical representations.

5.4.1 Stochastic Dominance

As expected, CDF charts varied significantly based on discount rates and field sizes. On an 80-acre field size, all the cumulative distributions of net present value of rain-fed production (with crop insurance) is first order stochastic dominant over irrigation production (without crop insurance) at all discount rates. Rain-fed production without crop insurance is second order stochastic dominant over irrigation production without crop insurance at all specified interest rates. However, extensive crossing among the CDFs for rain-fed production makes it difficult to identify the most dominant CDF under FSD. The CDF charts at all discount rates show that rain-fed production without crop insurance is second order stochastic dominated by rain-fed production with crop insurance. This means that on an 80-acre field size, all classes of producers or decision makers would prefer rain-fed production to irrigation and risk averse decision makers will prefer rain-fed production with crop insurance. The same pattern is observed at the various discount rates with the probability of obtaining negative net present values increasing as the discount rate increases. Figures 5.1 and 5.2, respectively, display the CDF charts of an 80-acre field size at 2% and 8% discount rates. As shown in Figure 5.2, irrigated production at 8% has over a 70% probability of generating negative net present values, making irrigated production less attractive relative to rain-fed production, which has a lower chance of generating negative returns.

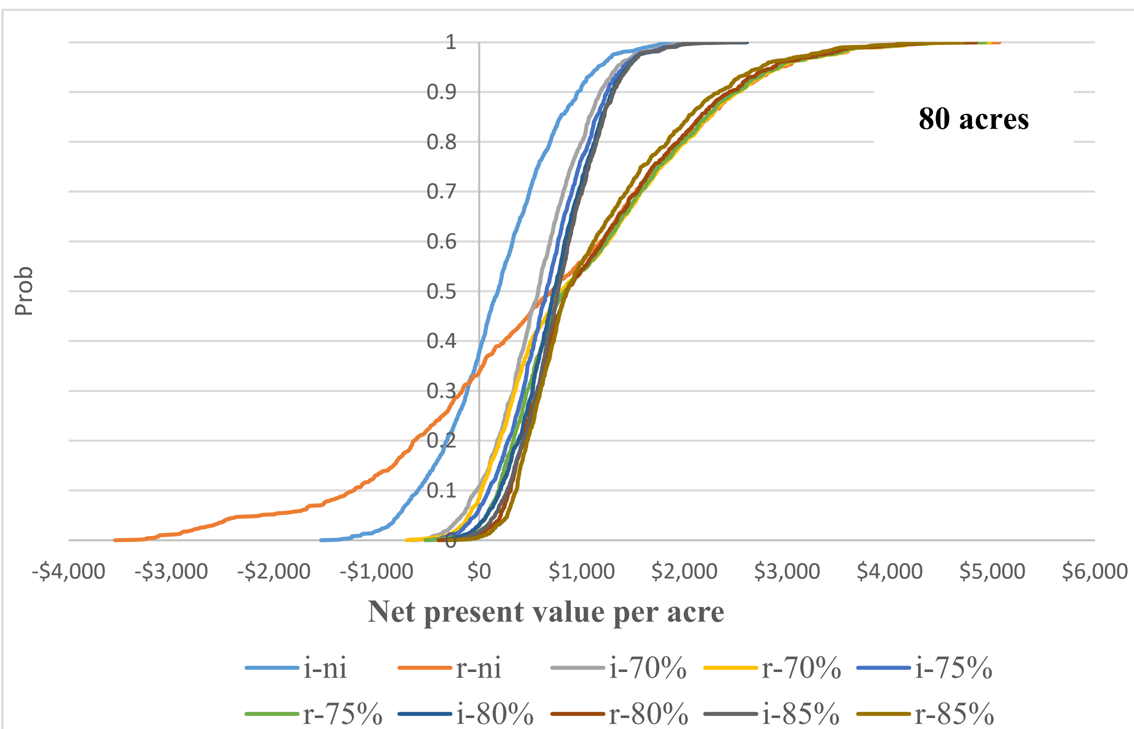

Figure 5.1 CDF at a 2% discount rate on 80 acres with up-front payment.

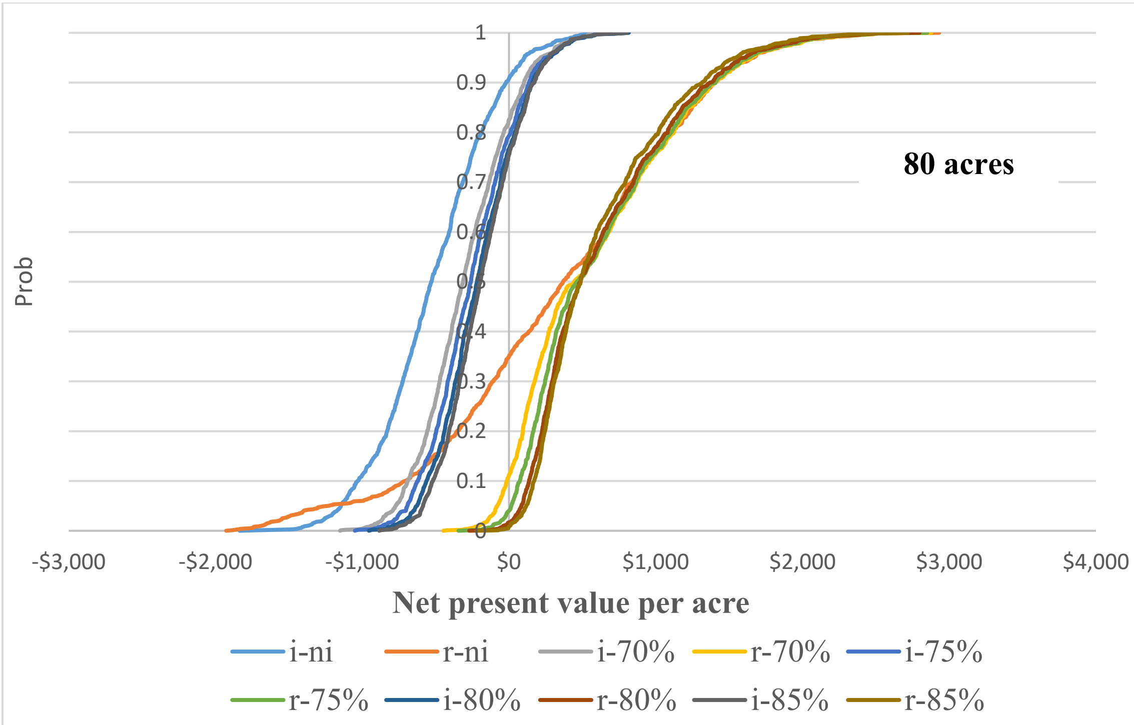

Figure 5.2 CDF at an 8% discount rate on 80 acres with upfront payment.

Regardless of how the irrigation investment is purchased (through financing or up-front payments), the net present value distribution of rain-fed and irrigated production on a 160-acre field size are close, which leads to extensive crossing among the CDFs, especially at low interest rates. Figure 5.3 reports the CDF chart for a 160-acre field size with an up-front payment for the irrigation investment at a 2% discount rate. All the CDFs for irrigated production at this level have less than a 15 percent chance of generating a negative net present value. The CDFs for rain-fed production with and without crop insurance is second order stochastic dominated by irrigation production with crop insurance. This means that risk averse decision makers would prefer to irrigate while protecting their revenues than to depend on rain-fed production. Irrigation without crop insurance is second order stochastic dominant over the complete distribution of rain-fed production without crop insurance.

As the discount rate increases, the probability of obtaining a negative present value increases at a higher rate for irrigation compared to rain-fed production. As shown in Figure 5.4, at a 10 percent discount rate, the net present value distribution of irrigation has a higher probability of generating negative net present values relative to rain-fed production. Making an up-front payment at a 10% discount makes irrigation less desirable for all classes of decision makers, as it becomes dominated by rain-fed production under FSD (Figure 5.4).

Similar to Figure 5.4, Figure 5.5 compares the cumulative distribution of net present values on a 160-acre field size at a 10% interest rate, but the irrigation investment is assumed to be financed over ten years. We found that both irrigation and rain-fed production without crop insurance are the least preferred options, as they are dominated by the other distributions. However, the decision to either irrigate or rely on dryland production with revenue protection under both scenarios will be dependent on the degree of risk aversion, because the extensive crossing among the CDFs makes it difficult to determine the most dominant scenario. Comparing Figures 5.4 and 5.5 confirms the fact that financing the investment generates high net present values and makes irrigation attractive even at higher interest rates.

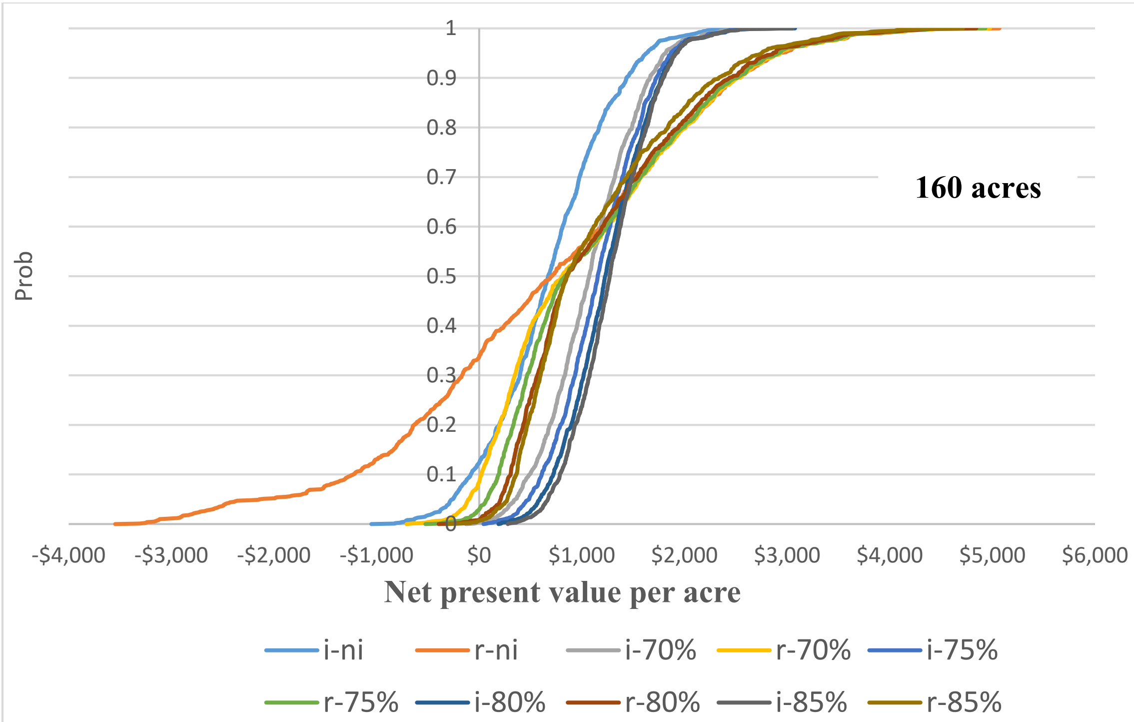

Figure 5.3 CDF at a 2% discount rate on 160 acres with up-front payment.

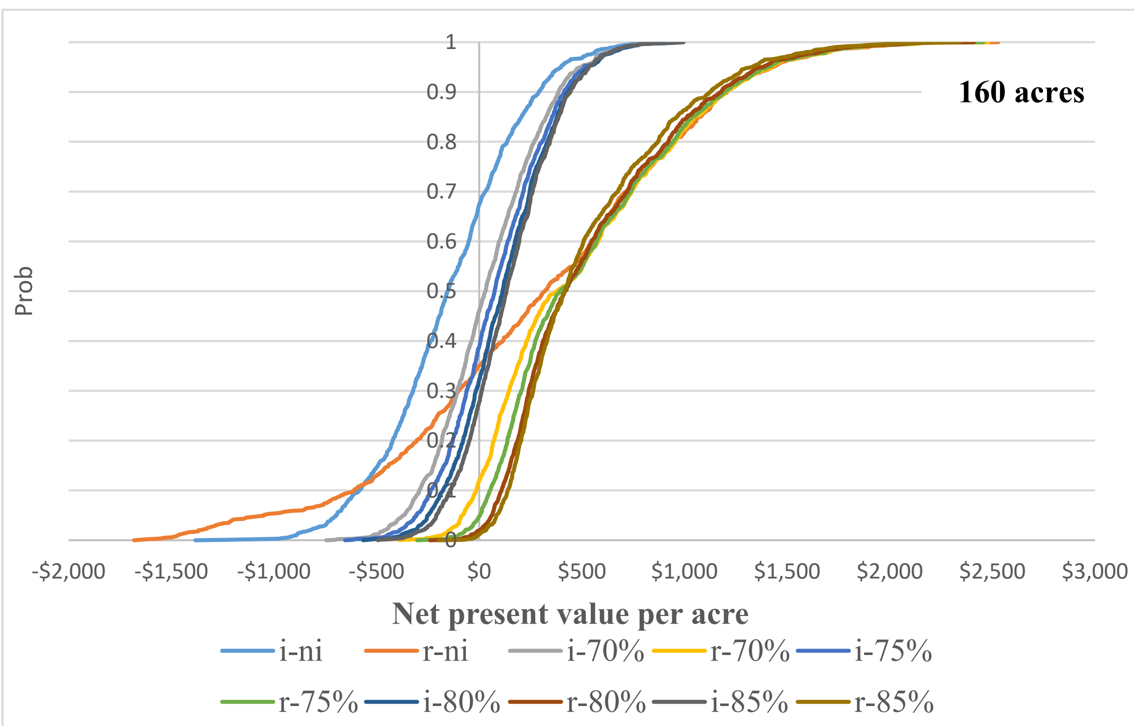

Figure 5.4 CDF at a 10% discount rate on 160 acres with up-front payment.

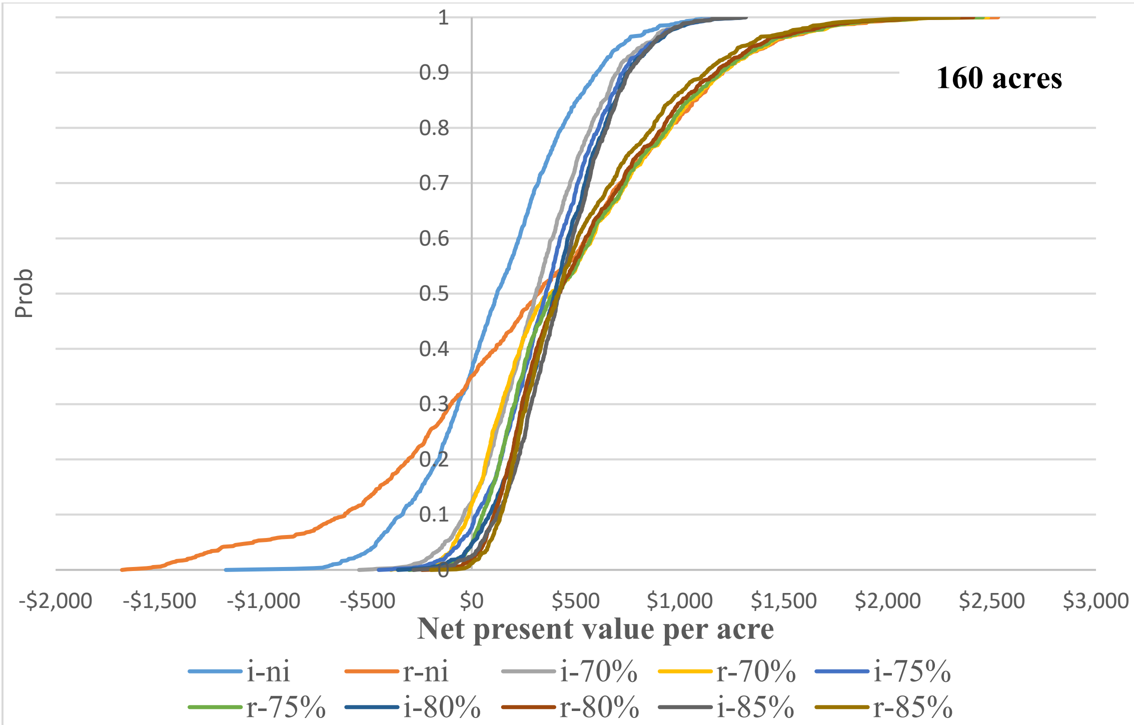

Figure 5.5 CDF at a 10% discount rate on 160 acres (financing investment).

5.4.2 SERF Analysis

Similar to the CDF charts shown above, five SERF charts were created. Each chart has ten net present value distributions ranked on their certainty equivalents (CE). The best option at each relative risk aversion level has the highest CE. For ease of ranking and interpretation, the CEs on each chart are adjusted to contain only positive values. This adjustment does not affect or change ranking among scenarios but only makes ranking easy, as it omits the negative net present values obtained, especially at high discount rates. The concern here is that the CEs are not the actual values that a decision maker assigns to the entire distribution. This is not a problem because all values were adjusted by the same amount.

The SERF charts for 80 acres (Figures 5.6 and 5.7) and 160 acres (Figures 5.8 and 5.9) at specific discount rates are used as examples to explain how different risk aversion levels influence decision making between irrigated and rain-fed production. From the summary statistics and CDF charts, we can conclude that investing in an irrigation reservoir on an 80-acre field size is not worth the construction cost, regardless of the discount rate used. This is also true in the SERF analysis. Figure 5.6 indicates that at a 2% discount rate, the average CE for the net present value distribution of rain-fed production is consistently higher than that of irrigated production for an 80-acre field.

All levels of risk averse decision makers (with Risk Aversion Coefficients between zero and four) prefer to depend on rainfall than to invest in an irrigation reservoir. Characterization of the relative risk aversion coefficient on the SERF charts are reported in Table 4.2. Figure 5.6 shows that for decision makers with low relative risk aversions, rain-fed production with crop insurance at an 80% coverage level is most preferred. Decision makers with very high risk aversion levels prefer to insure their rain-fed revenues at 85% coverage levels. Based on the average net present value estimates, we can conclude that irrigation is less preferred on small field sizes whether with or without crop insurance. The SERF chart shows that at a 2% discount rate, a very risk averse decision maker is indifferent between irrigating with revenue protection at 85% coverage levels and practicing dryland crop production with a 70% coverage level. Extreme risk averse decision makers prefer irrigation with an 85% coverage level to rain-fed production with a 70% coverage level.

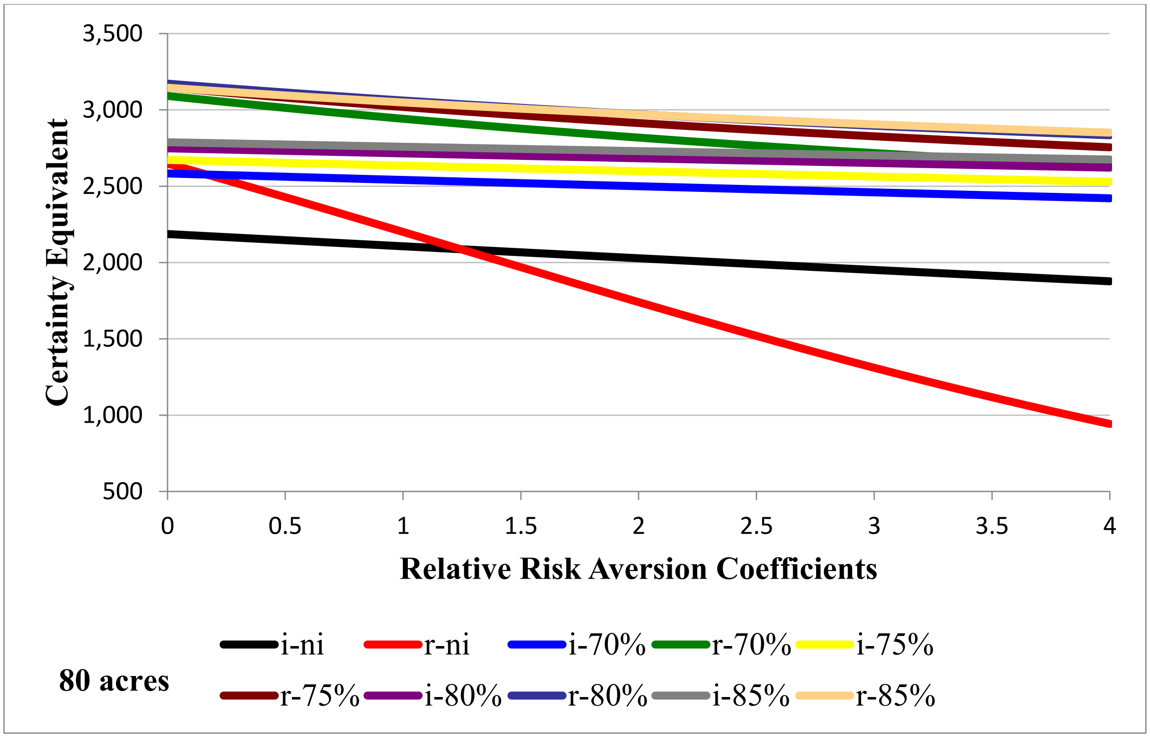

Figure 5.6 SERF analysis at a 2% discount rate on 80 acres with up-front payment.

The same pattern is observed as discount rate increases, but the CE reduces and the gap between rain-fed and irrigation production widens in favor of the former. Figure 5.7 shows an increase in the gap between the two scenarios at the 8% discount rate. The maximum average CE for irrigation which is observed at 85% coverage level decreases from about \$2,700 (at 2%) to about \$1,700 (at 8%). From Figure 5.7, it can be concluded that irrigated production with crop insurance (at a 75% and 70% coverage level) and without crop insurance are least preferred by decision makers due to their low CE. Based on the ranking of CEs, rain-fed production is the best option for decision makers on an 80-acre farm size. However, investors or producers with extreme relative risk aversion levels would prefer to irrigate and protect their revenues at 80% and 85% coverage levels than to depend on rainfall without crop insurance.

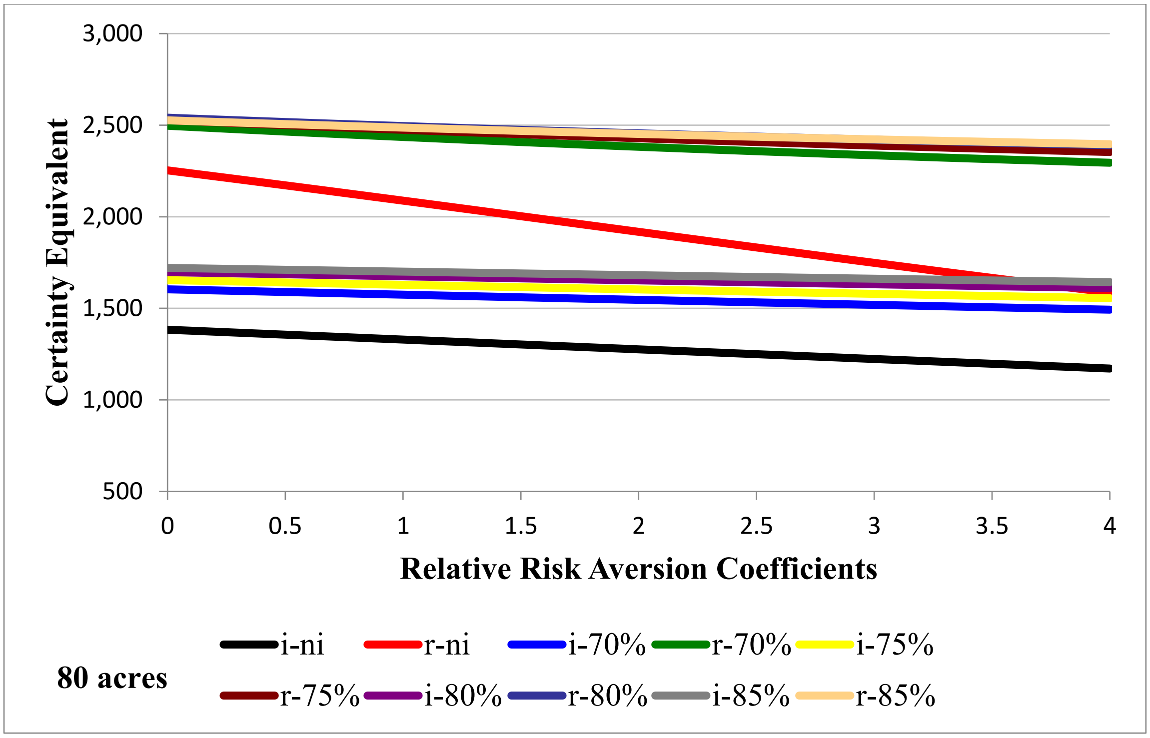

Figure 5.7 SERF analysis at an 8% discount rate on an 80-acre field size with up-front payment.

The difficulty in ranking alternative CDFs at 2% on 160 acres is overcome in the SERF analysis. As shown in Figure 5.8, we can conclude that at all level of relative risk aversion, decision makers would prefer to irrigate and insure their revenues at an 85% coverage level, followed by 80% and 75% coverage levels. Hardly risk averse decision makers are indifferent between irrigating at a 70% coverage level and depending on rainfall with an 85% coverage level. However, at risk aversion levels higher than one (somewhat risk averse), decision makers would rather irrigate with 75% of revenue protection than depend on rain-fed production. Figure 5.8 indicates that irrigation and rain-fed production without crop insurance are the two least preferred options at all risk aversion levels. Increases in interest rates make rain-fed production (without crop insurance) dominant over irrigation (without crop insurance) for decision makers with low relative risk aversion levels. However, irrigation remains a better option for decision makers with extreme risk aversion levels when discount rates increase (Figure 5.9).

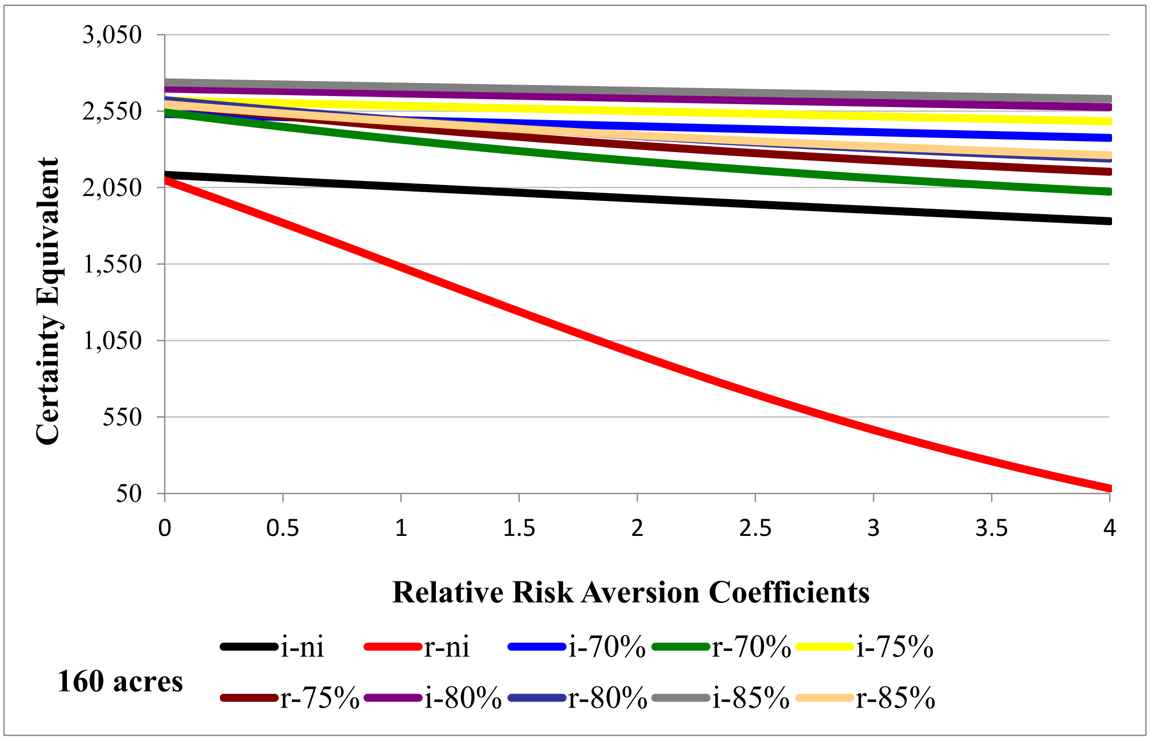

Figure 5.8 SERF analysis at a 2% discount rate on a 160-acre field size with up-front payment.

As expected, an increase in discount rate changes the rankings under a SERF analysis as shown in Figure 5.9. An increase in the discount rate makes irrigated production less desirable for all levels of risk aversion, as compared to rain-fed production on a 160-acre field size. This is observed when the discount rate is above 4%. In other words, the distribution of returns for irrigated production had a high CE relative to rain-fed production at the 4% discount rate. For all relative risk aversion coefficients (RRAC), the best options at the highest discount rate used in this research (10%) are rain-fed production with 85% and 80% crop insurance coverage levels. As coverage level increases, the effectiveness of crop insurance in reducing the variability in net present value increases, hence protection at a higher coverage level is preferred by decision makers with extreme risk aversion levels.

As shown in Figure 5.9, irrigation production with crop insurance has a CE that is higher than rain-fed production with no crop insurance when risk aversion levels are greater than 1 (somewhat risk averse). It should be noted that the reported SERF charts in Figures 5.7, 5.8 and 5.9 assume irrigation investment are paid up-front. Comparing the SERF chart at 160 acres with an assumption that the investment is financed, we found that at a 10% discount rate, rain-fed production at 85% and 80% coverage levels has CEs at all risk aversion levels that are similar to the results under the up-front payments. But making the irrigation investment with 85% and 80% coverage levels in crop insurance is preferred over rain-fed production at 75% and 70% coverage levels by very and extreme risk averse decision makers (Figure 5.10).

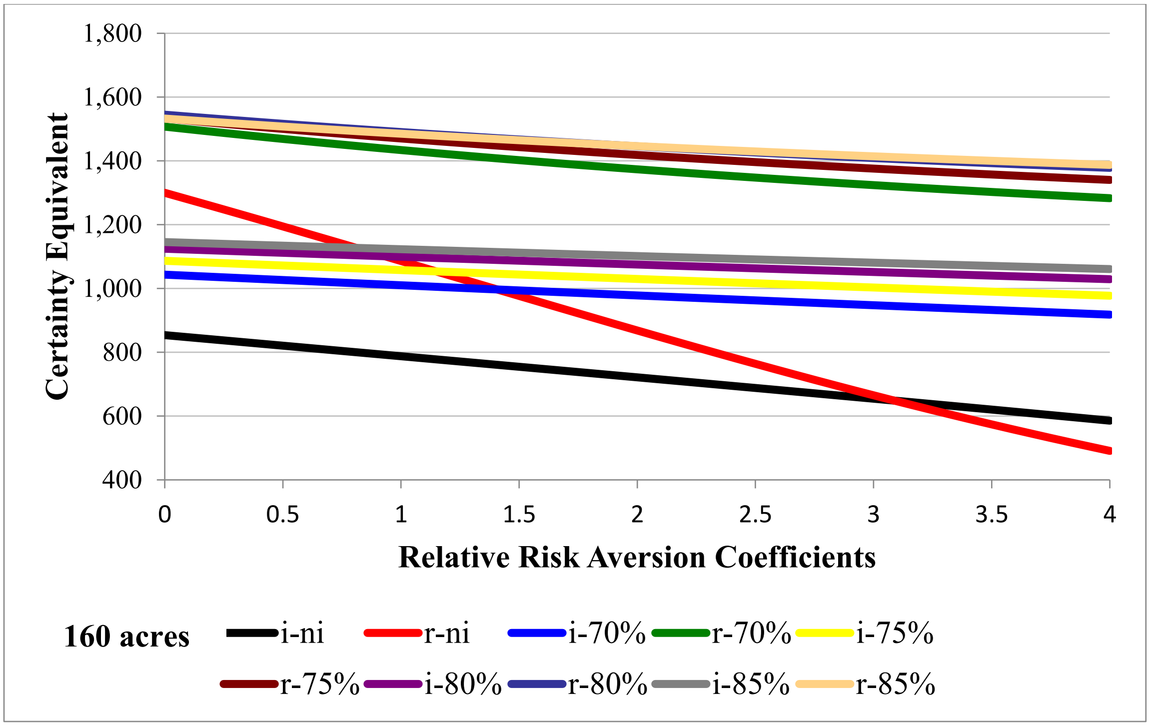

Figure 5.9 SERF analysis at a 10% discount rate on a 160-acre field size with up-front payment.

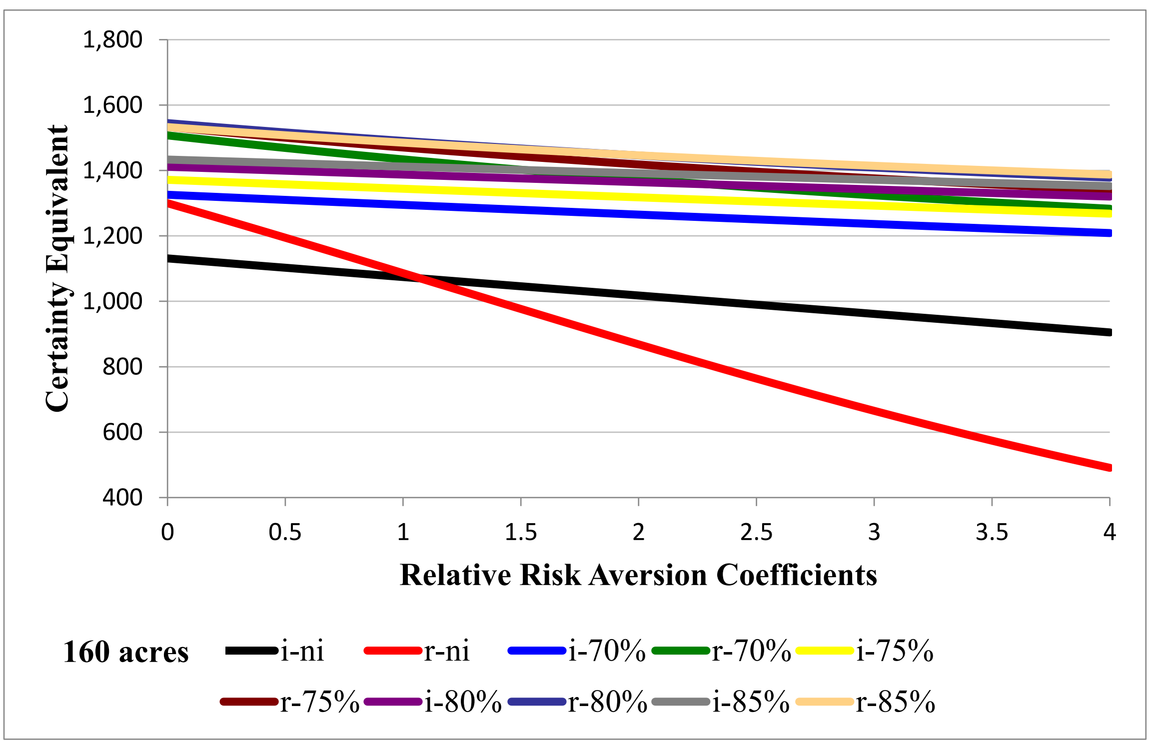

Figure 5.10 SERF at a 10% discount rate on 160 acres (financing investment)

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary of Findings

With access to groundwater for irrigation generally an impractical option for producers in East Mississippi, this study employs a stochastic benefit cost analysis to analyze the net present value estimates of investing in an on-farm water storage (OFWS) system and irrigating with a center pivot irrigation system (CPIS) in East Mississippi. Though the use of OFWS is gaining popularity in the area, little effort has been devoted to analyze its profitability or potential returns; hence, results from this study give good insight to producers and investors as to whether it is worthwhile to invest in the system or if producers would be better off depending on rainfall. The study takes into consideration a farm in Noxubee County on which a 17-acre irrigation reservoir has been constructed by the landowner. The landowner has provided details on construction costs of the irrigation system as well as access to the land for research purposes. The ratio of reservoir to irrigated area of the farm is used to estimate the net present value of investing in an irrigation reservoir for 80- and 160-acre field sizes. The riskiness of the investment is accounted for by incorporating stochastic prices, yields and weather.

A historical correlation matrix shows correlation between corn and soybean yields (irrigated and rain-fed), harvest time prices, and weather variables. This relationship is then incorporated into stochastic simulation models to generate correlated yields, prices, and the growing period's weather conditions. The stochastic simulated variables are incorporated into economic models to simulate field level returns and net present values for irrigating from a reservoir over a twenty-five year period. Net present value estimates are then compared to an alternative of "do nothing" or rely on rain-fed production for corn and soybean to determine which scenario will yield higher returns for producers.

Summary statistics indicate that the net present value of investing in an irrigation reservoir is highly dependent on the field size, irrigation technology and prevailing interest rates. The simulated net present value for rain-fed production is generally higher than that of irrigating from an irrigation reservoir. This is more evident when discount rates are high. The profitability of investing in an irrigation reservoir can be significantly increased, or rather the percentage of the net present value of rain-fed production falling above that of irrigated production can be reduced drastically if a more efficient irrigation system, which can irrigate the entire field, is used.

We found that given the prevailing interest rates, irrigating from a storage reservoir will be more profitable if the cost of investment can be financed through a series of payments rather than making an up-front payment. Reducing the construction costs of a reservoir through cost assistance opportunities for the system's environmental benefits will significantly increase the profitability of investing in an irrigation reservoir. Sensitivity analyses show that cost assistance should be well above 40% for such an irrigation investment to be worth its cost when discount rates are at 8% and 10%.

Protecting revenues under crop insurance significantly increases the net present value of both irrigation and rain-fed production. Crop insurance reduces the variability in revenues by reducing standard deviation and the range of minimum and maximum net present value estimates. Although crop insurance increases the net present value, these increases are not enough to make irrigation production worthwhile when discount rates are at 8% and 10%.

Cumulative distributive functions show that irrigation production has a high probability of generating negative net present values compared to rain-fed production. The probability of having a negative net present value can be significantly reduced with revenue protection under crop insurance. On the whole, without revenue protection for both production scenarios, relying on rainfall is preferred to irrigation production when the prevailing discount rate is 4% or higher. Based on relative risk aversion levels, stochastic efficiency analyses shows that all levels of relative risk averse decision makers will prefer to irrigate and insure their revenues at 85% coverage levels on a 160-acre field size when discount rates are at 2% or 4%. Financing the irrigation investment makes irrigation the better option at a 6% discount rate when revenues are protected at high coverage levels.

Irrigation production is the less preferred option among the two scenarios for risk averse decision makers when discount rates are at 6% or higher. We found that investing in an irrigation reservoir on small field sizes is not a good option for risk averse decision makers. This is in accordance with Boulden et al. (2014), who reported that smaller field sizes may not have enough acreage needed to realize the benefits of OFWS. However, based on stochastic efficiency analysis, we found that extremely risk averse decision makers may prefer to irrigate and protect their revenue at higher coverage levels than to depend on rainfall.

Although no government incentives currently exist for construction of OFWS by crop producers in East Mississippi, the probability of obtaining positive and higher net present values of irrigating from an OFWS can be increased should crop producers receive an incentive for investing in OFWS. As mentioned in previous sections, studies such as Popp et al. (2003) and Tagert et al. (2015) have reported a significant amount of pollutants are prevented from moving downstream from agricultural fields by OFWS. But the economic impact of the reduced sediment and nutrients flowing downstream was not quantified in this study. In other words, the simulated net present value distributions for investing in an OFWS do not take into consideration all of the potential benefits that come with it. This means the societal benefit from a producer investing in an OFWS system could potentially be much higher.

With the increase in uncertainty in rainfall distribution in recent years, many producers wish to supplement rainfall with irrigation water. There are different sources of water for irrigation, but the use OFWS is gaining popularity due to the multiple benefits that come with it. Without accounting for all potential benefits to a producer, findings indicate that a producer's decision to invest in an OFWS is undoubtedly dependent on the existing rate of return and risk aversion level. Reported net present value estimates for investing in an OFWS are lower than rain-fed production when discount rates are just above 2%. Providing crop producers in the study area with government incentives to prevent sediment loss and inflow of pollutants from agricultural lands through the use of OFWS will increase its profitability significantly, and make it more desirable as compared to rain-fed production at higher discount rates.

6.2 Limitations

This study is one the few attempts that has been made to analyze the economics of an OFWS system in Mississippi. Though reported findings give insight into the profitability of investing in an OFWS system in the study area, there are a few limitations that should be addressed in future studies. First, the ratio of reservoir to irrigated area from one farm as a representative for other farm sizes in the study area may not be a precise representation. Ouyang et al. (2016), found that a 1-ha pond size is optimal or a reasonable choice for farmers to irrigate a 18-ha soybean field. Their estimated ratio is different from an approximated 1:13 ratio by staffs from NRCS. The ratio used in this study resulted in an 8-acre reservoir size for a 160-acre irrigated area; although the reservoir at the study site for this research is much deeper than those in the abovementioned studies. Whether or not these ratios influence the net present value estimates, it would be ideal to use actual or observed reservoir to field size ratios to obtain representative estimates for various field sizes. In addition, we did not take into account the quality of the land taken out of production. We assumed that all areas of the field were of an equal quality; however, if the OFWS system is put on an area of the field that is less productive, the opportunity cost will be much lower.

Second, the use of farm level data would be an improvement over aggregated county-level data. By generating farm-level distributions, we could achieve our aim of increasing the variability in yields which are likely to be observed at the farm level. However, the captured risk may still differ from producer to producer on the farm level. Hence, the use of actual farm level yield data would be ideal for such a study.

6.3 Future Work

The current study is the second to have applied economic tools to analyze the economics of OFWS in Mississippi and the first in East Mississippi. Given the growing popularity of these systems in the state, there is a need for more economic feasibility and profitability studies on the use of OFWS systems under different conditions in Mississippi and across the U.S. Future work can improve on this study by using techniques such as benefit transfer or willingness to pay or accept estimates from surveys to capture the environmental benefits that were not taken into account. Increasing the life span of OFWS could also allow the estimated cash flows to accumulate over a longer period of time to meet the cost of investment at higher interest rates. In addition, this study compared two alternatives: rain-fed vs. OFWS. The cost of irrigation investment used takes into account the cost a CPIS. Future studies could compare returns from irrigating with OFWS to that of alternative sources of irrigation water and other irrigation technologies.

REFERENCES

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

Arthur K. J. (2001). “Hydrogeology, Model Description, and Flow Analysis of the Mississippi River Alluvial Aquifer in Northwestern Mississippi.” U.S. Geological Survey Water-Resources Investigations. Report 01-4035.

Barham E. H. B., Robinson, J. R.C, Richardson, J.W., Rister, M. E., (2011). “Mitigating Cotton Revenue Risk through Irrigation, Insurance and Hedging.” Journal of Agricultural and Applied Economics, 43: 529-540.

Boehlje M., (2002). “Risk in Agriculture.” New Challenges New Approaches.” Staff Paper 0-07. Department of Agricultural Economics. Purdue University, November 2002. http://ageconsearch.umn.edu/bitstream/28614/1/sp02-07.pdf. Retrieved on 02/25/2017.

Boggess, W.G., Lynne, G.D., Jones, J.W. and Swaney, D.P., (1983). “Risk-return Assessment of irrigation decisions in humid regions”. South. J. Agric. Econ., 15: 135-143.

Boggess W.G and Amerling C.G, (1983). “A Bioeconomic Simulation Analysis of irrigation investments.” Southern journal of agricultural economics.

Bouldin, J. L., Bickford, N. A., Stroud, H. B., and Guha, G.S., (2004). “Tail water Recovery Systems for Irrigation: Benefit/Cost Analysis and Water Resource Conservation Technique in Northeast Arkansas.” Journal of the Arkansas Academy of Science, 58:25-31.

Boyer, C. N., Larson, J.A., Roberts, K. R., McClure, T. A., Tyler, D. D., Smith, A.S., (2014). “Probality and Risk Analysis of Soybean Planting Date by Maturity Group.” Agronomy Journal. 107: 2253-2262.

Boyer, C. N., Stefanini, M. Larson, J.A., Smith, A.S., Mengistu, A., and Bellaloui, (2015). “Probality of Irrigated Corn Being Profitable in Humid Region.” Selected Paper prepared for presentation at the Southern Agricultural Economic Association.

Carruthe W. G., Paz, J.O., Tagert, M.L, Guzman, S.M and Oldham, L. J., (2014). "Reusing Irrigation water from Tailwater Recovery Systems: Implication on Field and Stream-Level and Stream-Level Nutrient Status. Asabe Joint Meeting Presentation. Paper Number 141913747.

Charles et al. (2015) "Current Agricultural Practices of Mississippi Delta." Mississippi and Forestry Experiment Station.

Chavas J.P (2004). "Risk Analysis in Theory and Practice." Academic Press, San Diego.

Coble K.H., Heifner R. G., and Zuniga. M (2000). "Implication of Crop Yield and Revenue Insurance for Producer Hedging". Journal of Agricultural and Resource Economics. 25(2).432-452.

Coble, K., and R. Dismukes., (2008). "Distributional and Risk Reduction Effects of Commodity Revenue Program Design." Review of Agricultural Economics.30, No.3. 543-553.

Coble, K.H., M. Zuniga, and R. Heifner. (2003) ''Eval-uation of the Interaction of Risk Management Tool for Cotton and Soybeans." Agricultural Systems 75:323–40.

Cooper, J., Zulauf, C., Langemeier, M., and Schnitkey, G., (2012). "Implications of within County Yield Heterogeneity for Modeling Crop Insurance Premiums." Agricultural Finance. Review 72:134-155.

Cooper J. (2009). "Construction Farm Level Yield Densities from Aggregated Data: Analysis and Comparison of Approaches". Paper Prepared for the Agricultural and Applied Economics Associations and ACCI Annual Meetings. Milwaukee, WI July 26-28.

Czarneck J.M, Omer B.R. and Dyer L.J (2016). "Quantifying Capture and Use of Tailwater Recovery. Systems". Journal of Irrigation and Drainage Engineering. 05016010:1-6.

Dalton T.J., Porter, G. A., and Window, N.G., (2004). "Risk Management Strategies in Humid Productions Regions." A comparsion of supplemental irrigation and crop insurance. Agric. Resource Econ. Rev.33. 220- 232.

Pimental, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark S., Poon, E., Abbett, E., and Nandagopal, S., (2004). "Water Resources: Agricultural and Environmental Issues." Bio Science. 54:909-918.

DeJonge K.C., Kaleita, B.L., and Thorp, K. R., (2007). "Simulating the effects of spatially variable irrigation on corn yields, costs, and revenue in Iowa." Agricultural water management. 92:99-109.

Delta Farm Press, (2012). "Irrigation and cotton Acre Increase in East Mississippi." http://www.deltafarmpress.com/cotton/east-mississippi-irrigation-and-cotton-acres-increase. Accessed on 12/20/2016.

D'iaz R., Rabalais N. N and Breitburg D. L., (2012). "Agricultural Impact on Aquaculture Hypoxia and Eutrophication in Marine Waters." A Report for OECD. [https://www.oecd.org/tad /sustainable-agriculture/49841630.pdf](https://www.oecd.org/tad/sustainable-agriculture/49841630.pdf). Retrieve on 30/03/2017

Doering, O., Diaz-Hermelo, F., Howard, C., Heimlich, R., Hitzhusen, F., Kaasmierczak, R., Lee, J., Libby, L., Milon, W., Prato, T., and Ribaubo, M., (1999). "Evaluation of the Economic Costs and Benefits of Methods for Reducing Nutrient Loads to the Gulf of Mexico." Topic 6 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 20. NOAA Coastal Ocean Program, Silver Spring, MD. 115

Dowgert. M.F., (2010). "The Impact of Irrigated Agriculture On A Stable Food Supply." Proceedings of the 22nd Annual Central Plains Irrigation Conference, Kearney, NE., February 24-25, 2010.

Drollete S. A., (2009). "Managing Production Risk in Agriculture" Department of Applied Economics Utah State University, United States. RMA Extension Publication.

Ecological Society of America (2012). "Hypoxia" https://www.esB.org/esa/wp-content/uploads/2012/12/hypoxiB.pdf. Retrieve on 30/03/2017.

Epperson, J.E., Hook, J.E and Mustafa. Y.R., (1993). "Dynamic Programming for Improving Irrigation. Schooling Strategies of Maize." Agricultural System. 42:85-101.

Evett, S., Carman, D and Bucks, D. (2003). 'Expansion of Irrigation in the Mid-South United Stated: Water Allocation and Research Issues'. Proceedings, 2nd International Conference on Irrigation and Drainage, Water for a Sustainable World – Limited Supplies and Expanding Demand, May 12-15, 2003, Phoenix, Arizona. U.S. Committee on Irrigation and Drainage. 247-260.

Falconer, Lewis and Krutz (2015). "Economic Feasibility of Tail water Recovery System in Mississippi Delta." Selected paper prepared for presentation at the Southern Agricultural Economic Association (SAEA) Annual Meeting, Atlanta, GA, and January 1-February 3, 2015.

Fiener, P, Auerswald, K. and S. Weigand (2005). "Managing erosion and water quality in agricultural watersheds by small detention ponds." Agriculture, Ecosystems andEnvironment. 110 132–142.

Food and Agriculture Organization (FAO), (2016). "Irrigated Areas, Irrigated crops and Environment" http://www.fao.org/nr/water/aquastat/didyouknow/index3.stm. Accessed on 01/20/2016.

Harwood, J., Heifner, R., Coble, K., Perry, J., and Somwaru, A., (1999). "Managing Risk in Farming" Concept, Research and Analysis." Economic Research Service – USDB. Washington, DC, 20036, 583.

Johnston, J. F., and Dowbenko, R., (2004), "Essential Element in Corn" http://www.farmwest.com/node/94. Accessed on 02/20/2016.

Kahan D. (2008). "Managing Risk in Farming". Farm Management Extension Guide. Food and Agriculture Organization of the United Nations. http://www.fao org/uploads/ media/3-ManagingRiskInternLores.pdf. Retrieved on 02/05/2017.

Kay, R.D., W.M .Edwards and P.A Duffy (2008). 'Farm Management' (6th ed). New York, NY. McGraw-Hill.

Kebede, H., Fisher, D.K., Sui, R. and Reddy, K.N. (2014). 'Irrigation Methods and Scheduling in the Delta Region of Mississippi: Current Status and Strategies to Improve Irrigation Efficiency'. American Journal of Plant Sciences, 5, 2917-2928.

Kendall C. DeJonge and Amy L. Kaleita (2006). "Simulation of Spatially Variable Precision Irrigation and Its Effects On Corn Growth Using CERES Maize." ASABE Paper No. 062119. St. Joseph, Mich.

Kiemeyer III, L. R., Paz, J. O., Tagert, M. L., and Jonathan, W. P., and McCaraven, E. K., (2012). "On-Farm Water Storage System in Porter Bayou Watershed." Mississippi. An ASABE Meeting Presentation. Paper No 12-1337631.

Konikow, L.F., (2013), Groundwater depletion in the United States (1900−2008): U.S. Geological Survey Scientific Investigations. Report 2013−5079, p.63.

Lamm, F. R., O'Brien D.M., and D. H. Rogers (2015). "Economic Comparison of Subsurface Drip and Center Pivot Sprinkler Irrigation Using Spreadsheet Software." American Society of Agricultural and Biological Engineers 31(6): 929-936.

Lin S., Mullen J.D and Hoogenboom G (2008). "Farm-Level Risk Management Using Irrigation and Weather Derivatives. Journal of Agricultural and Applied Economics. 40, 2. 485-492.

Maupin, M. A., Kenny, J. F., Hutson, S. S., Lovelace, J. K., Barber, N. L., and K. S. Linsey (2014). "Estimated use of water in the United States in 2010." U.S. Geological Survey Circular 1405,56. http://dx.doi.org/10.3133/cir1405.

Mississippi Department of Agricultural and Commerce (MDAC), (2016). “Mississippi Agricultural Overview.” https://www.mdac.ms.gov/agency-info/mississippi-agriculture-snapshot/. Accessed on 03/27/2017.

Mississippi State University (MSU) Planning Budgets, (2016). “Planning Budget for Non-Delta Areas’. Mississippi State University, Department of Agricultural Economics. Budget Reports.

Moore M. T., Pierce, R. J and Farris L.J., (2015). “Water-Quality Analysis of an intensively used On-Farm Storage Reservoir in the Northeast Arkansas Delta’. Arch Environ Contam Toxicol. 69:89–94.

National Resource and Conservation Service, (2014). Conservation Practice Standard (CPS): Irrigation System, Tailwater Recovery Systems.

National Resource and Conservation Service, (2013). Conservation Practice Standard (CPS): Irrigation System, Tailwater Recovery Systems.

National Oceanic and Atmospheric Administration (NOAA), (2009). “Dead zones: Hypoxia in the Gulf of Mexico” Fact sheet. http://www.noaanews.noaa.gov /stories2009/pdfs/new%20fact%20sheet%20dead%20zones final.pdf. Accessed on 11/11/2016.

National Science and Technological Council (2003). “An Assessment of Coastal Hypoxia and Eutrophication in U.S. Waters” http://oceanservice.noaB.gov /outreach/pdfs /coastalhypoxiB.pdf. Accessed on 03/05/2017.

Organization of Economic Co-operation and Development (OECD), (2009) “Managing Risk in Agriculture Holistic Approach” http://www.oecd.org/agriculture/ agricultural policies/45558582.pdf.

O’Brien, D. M., Rogers, D. H., Lamm F.R., Clark., G. A., (1998). “An Economic Comparison of Subsurface Drip and Center Pivot Sprinkler Irrigation System.” American Society of agricultural Engineers. Vol 14(4):391-398.

O’Neill M.P and Dobrowolski J.P., (2005). CSREES Agricultural Water Security White Paper. Washington, DC. USDA.

Ouyang, Y., Feng, Gary, F., Read, J., Leininger, T. D and Jenkins, J. N., (2016). “Estimating the ratio of pond size to irrigated soybean land in Mississippi: A Case study.” Water Science and Technology:Water Supply.

Ouyang, Y., Feng, Paz, J. O., Gary, F., Read, J., Leininger, T. D and Jenkins, J. N., (2017). “A model to Estimate Hydrological Processes and Water Budget from an Irrigation Farm in Mississippi.” Water Resource Management. 31:2225-2241

Richardson J.W (2008). “Simulation for Applied Risk Management’. College Station, TX: Department of Agricultural Economics, Texas A&M University.

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

Ritshard R. L, Cruise. J.F and Hatch U.L (1999). “Spatial and Temporal Analysis of Agricultural Water Requirements in the Gulf Coast of the United States” Journal of the American Water Resource Association. Vol. 35, No. 6

Sassenrath, G., Schmidt, A., Schneider, J., Tagert, M.L., Van Riessen, H., Corbitt, J.Q., Rice, B., Thornton, R., Prabhu, R.,; Pote, J., and Wax, C., (2013). “Development of the Mississippi Irrigation Scheduling Tool-MIST.” Mississippi Water Resources Conference. Irrigation Practices and Management.

Stubbs M. (2016). “Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management PracticeS”. Congression Research Service. https://fas.org/sgp/crs/misc/R44158.pdf. Retrieved on 11/11/2016

Sinobas. L. R. (2017, April). “Environmental Benefits and Concerns of Center-Pivot Irrigation” Web log Post Retrieved 05/20/2017 from http://environmentalscience.oxfordre.com /view/10.1093/acrefore / 9780199389414.001.0001/acrefore- 9780199389414-e-251.

Tagert et al. (2015). ‘On-farm Water storage Systems and Irrigation Scheduling in Mississippi’. UCOWR/NIWR/CUAHSI Annual Conference USDA/WRRC Track.

The United Nations Educational, Scientific and Cultural Organization (UNESCO)-World Water Assessment Program (WWAP), 2012. “Managing Water from Uncertainty and Risk. Fact and figures.

U.S EPA (2002). National Management measures for the control of non-pollution from agriculture. National Center for Environmental Publications (NSCEP), Cincinnati, OH.

United State Department of Agriculture (USDA) –National Agricultural Statistics ((NASS), (2012). How important is irrigation to U.S Agriculture. USGS (2000). Irrigation water use. Retrieved from http://water.usgs.gov/edu/wuir.html. Accessed on 12/11/2016.

United State Department of Agriculture (USDA) –National Agricultural Statistics (NASS), (1997) “Pond, Planning, Design Construction. Agriculture Handbook Number 590.

United State Department of Agriculture (USDA) –National Agricultural Statistics (NASS), (2010). "Field Crops Usual Planting and Harvesting Dates" Agriculture Handbook Number 628.

United State Department of Agriculture (USDA)- Risk Management Agency (RMA), (2016). Premium Cost Calculator. https://ewebapp.rma.usda.gov/apps/ cost estimator/. Accessed on 12/20/2016.

United State Department of Agriculture (USDA), (2016). Mississippi River Basin Healthy Initiative (MRBI). Progress Report 2016. https://www.nrcs.usda .gov/wps/portal/nrc s/detailfull/ national/home/? cid=stelprdb1048200. Accessed on 02/20/2017.

United State Department of Agriculture (USDA), (2013). Mississippi River Basin Healthy Initiative (MRBI). Progress Report 2016. https://www.nrcs.usda .gov/wps/portal/nrc s/detailfull/ national/home/? cid=stelprdb1048200. Retrieved on 02/20/2017.

United State Department of Agriculture (USDA)-Risk Management Agency (RMA), (2016). "About the Risk Management Agency" RMA Fact Sheet.

United State Department of Agriculture (USDA)-Economic Research Report (2016). "Risk in Agriculture" https://www.ers.usda.gov/topics/farm-practices-management/risk-management/risk-in-agriculture/ Accessed on 01/112017.

United State Department of Agriculture (USDA) (1910). "Soil Survey of Noxubee County, Mississippi". Soil Conservation. Research. https://www.nrcs.usda.gov/ Internet/FSE _MANUSCRIPTS/ Mississippi/ noxubeeMS1986/ Noxubee.pdf. Retrieved on 03/11/2017.

United State Department of Agriculture (USDA) (2012). "Census of Agriculture". Noxube County Profile, Mississippi https://www.agcensus.usda.gov/Publicatio ns/2012 /Online_Resources/County Profiles/ Mississippi/cp28103.pdf. Retrieved on 03/11/2017.

U.S Climate Data (2016). Climate Conditions for Brooksville, Noxubee County, and Mississippi.http://www.usclimatedata.com/climate/brooksville/mississippi/ united- states/usms0481. Accessed on 05/12/2016.

Vandeveer, L. R., Paxton K. W. and Lavergne D. R., (1989). "Irrigation and Potential Diversification Benefits in Humid Climates" Southern Journal of Agricultural Economics.

Velandia, M., Rejesus, R. M., Knight, O. T., and Sherrick, B. J., (2009). "Factors Affecting Farmers." Utilization of Agricultural Risk Management Tools: The Case of Crop Insurance, Forward Contracting and Spread Sales". Journal of Agricultural and Applied Economic, 41, 107-123.

Wailes, E. J., Popp, J., Young, K. B., and Smart, J., (2004). "Economics of On-Farm Reservoirs and other Water Conservation Improvements on Arkansas Rice Farms." AAES Research Series 517. 426-432

Williams, J. R., Richard, V. L., Reed, M. S., Lamm, F. R and DeLano, R. D.,(1996). "Net Returns for Grain Sorghum and Corn under Alternative Irrigation Systems in Western Kansas." The Great Plains Symposium 1996: The Ogallala Aquifer March 5-6. Colby Community College, Colby, KS. No. 96-3.

Zerbe, R..O., and Bellas. B.S. (2006). "A Primer for Benefit-Cost Analysis." Cheltenham, UK. Northampton, MA, USB. Edward Elgar Publishing Limited.

APPENDIX A

SENSITIVITY ANALYSIS TABLES

Table A.1 Sensitivity analysis on 80 acres (with up-front payment)

	%	2%	4%	6%	8%	10%
		NPV in U.S $/acre				
	20	268	(40)	(266)	(435)	(564)
NI	**20**	105	(203)	(430)	(599)	(729)
	40	349	41	(185)	(353)	(483)
	40	23	(286)	(512)	(682)	(812)
	20	665	280	(3)	(214)	(376)
70%	**20**	502	116	(167)	(379)	(540)
	40	746	361	79	(133)	(294)
	40	419	33	(250)	(462)	(623)
	20	754	351	57	(164)	(332)
75%	**20**	590	187	(108)	(328)	(497)
	40	835	432	138	(82)	(250)
	40	508	105	(190)	(411)	(580)
	20	830	413	108	(120)	(295)
80%	**20**	666	249	(56)	(200)	(460)
	40	911	494	189	(39)	(213)
	40	583	166	(139)	(368)	(480)
	20	870	446	135	(97)	(275)
85%	**20**	706	281	(29)	(262)	(440)
	40	951	527	217	(15)	(193)
	40	623	199	(112)	(345)	(523)

Reported values reflects ±20% and ±40% variations in cost of irrigation reservoir.
Bold percentages represents increase in reservoir cost.

Table A.2 Sensitivity analysis on 160 acres (with up-front payment)

	%	**2%**	**4%**	**6%**	**8%**	**10%**
		NPV in U.S $ /acre				
	20	760	453	229	61	(67)
NI	**20**	605	297	72	(97)	(226)
	40	837	530	306	139	11
	40	526	218	(7)	(176)	(306)
	20	1,365	942	632	400	224
70%	**20**	1,210	786	475	243	66
	40	1,441	1,018	709	478	302
	40	1,131	707	396	163	(14)
	20	1,324	908	604	377	203
75%	**20**	1,169	752	447	219	45
	40	1,400	984	681	454	281
	40	1,090	673	368	139	(35)
	20	1,248	846	552	333	165
80%	**20**	1,092	690	396	175	7
	40	1,324	923	629	410	243
	40	1,014	611	316	96	(73)
	20	1,159	774	493	283	122
85%	**20**	1,003	618	336	125	(36)
	40	1,235	851	570	360	200
	40	924	539	256	45	(116)

Reported values reflects ±20% and ±40% variations in cost of irrigation reservoir. Bold percentages represents increase in reservoir cost.

Table A.3 Sensitivity analysis on 408 acres (with up-front payment)

	%	**2%**	**4%**	**6%**	**8%**	**10%**
		NPV in U.S /acre				
	20	623	314	88	(82)	(211)
NI	**20**	492	182	(45)	(215)	(344)
	40	688	379	153	(16)	(145)
	40	425	115	(112)	(282)	(412)
	20	1,024	637	354	142	(20)
70%	**20**	893	505	221	9	(154)
	40	1,089	702	419	208	46
	40	826	438	154	(59)	(221)
	20	1,114	709	414	192	24
75%	**20**	982	577	281	59	(110)
	40	1,179	775	498	258	90
	40	916	510	214	(8)	(177)
	20	1,190	772	465	236	62
80%	**20**	1,059	640	333	103	(72)
	40	1,255	837	531	302	128
	40	992	573	266	36	(139)
	20	1,231	805	493	260	82
85%	**20**	1,100	673	361	127	(51)
	40	1,296	870	559	326	148
	40	1,033	606	293	60	(119)

Reported values reflects ±20% and ±40% variations in cost of irrigation reservoir. Bold percentages represents increase in reservoir cost.

Table A.4 Sensitivity analysis on 160 acres (financing investment)

	%	**2%**	**4%**	**6%**	**8%**	**10%**
		NPV in U.S $/acre				
	20	747	523	370	265	191
NI	**20**	573	366	227	134	71
	40	832	600	440	328	249
	40	484	285	154	67	9
	20	1,243	852	641	492	385
70%	**20**	895	694	498	361	265
	40	450	928	711	555	443
	40	528	614	424	294	204
	20	1,248	928	704	545	431
75%	**20**	1,074	770	561	414	311
	40	1,332	1,004	773	608	489
	40	985	689	487	347	249
	20	1,329	993	758	591	471
80%	**20**	1,155	836	615	461	351
	40	1,413	1,069	827	654	528
	40	1,065	755	542	394	289
	20	1,372	1,029	788	617	493
85%	**20**	1,198	871	645	486	373
	40	1,456	1105	857	680	551
	40	1,109	790	571	419	311

Reported values reflects ±20% and ±40% variations in cost of irrigation reservoir. Bold percentages represents increase in reservoir cost.

APPENDIX B

CUMULATIVE DISTRIBUTION OF FUNCTION OF NET PRESENT VALUE FOR

ALTERNATIVE SCENARIOS

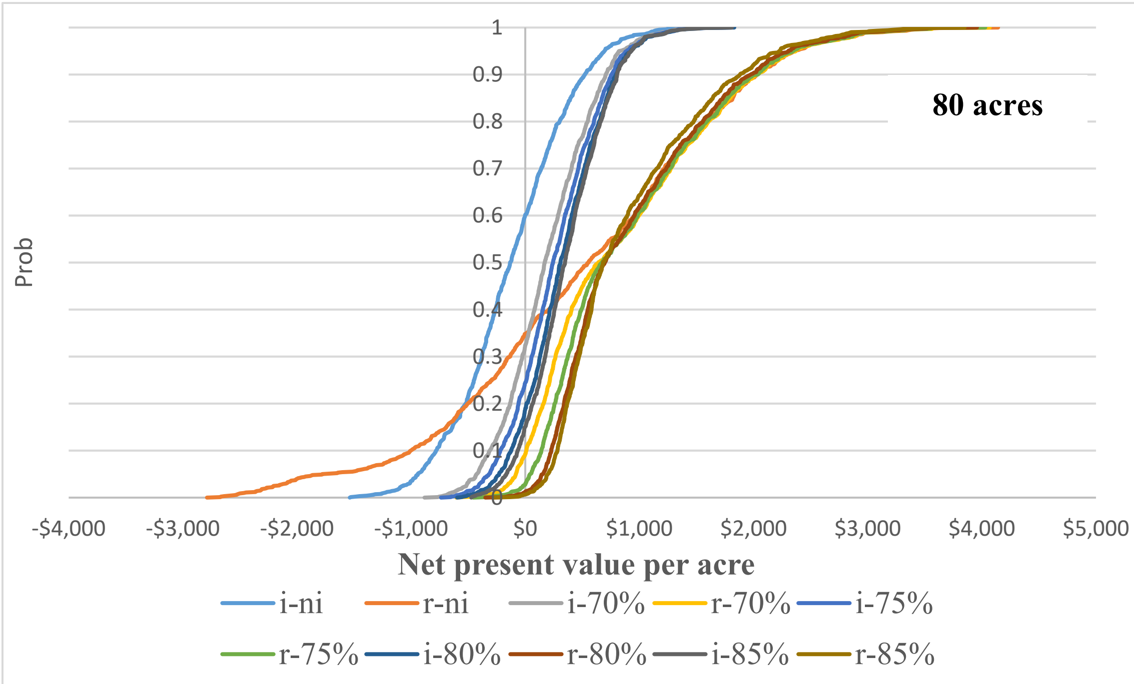

Figure B.1 CDF at 4% discount rate on 80 acre field size

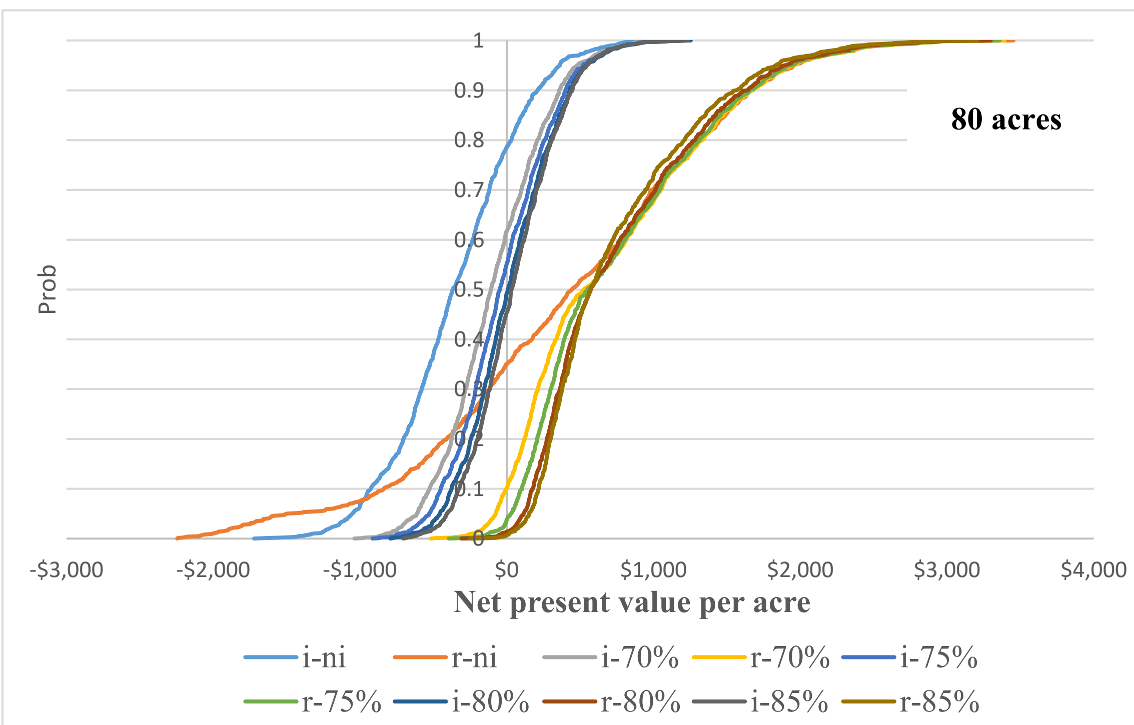

Figure B.2 CDF at 6% discount rate on 80 acre field size

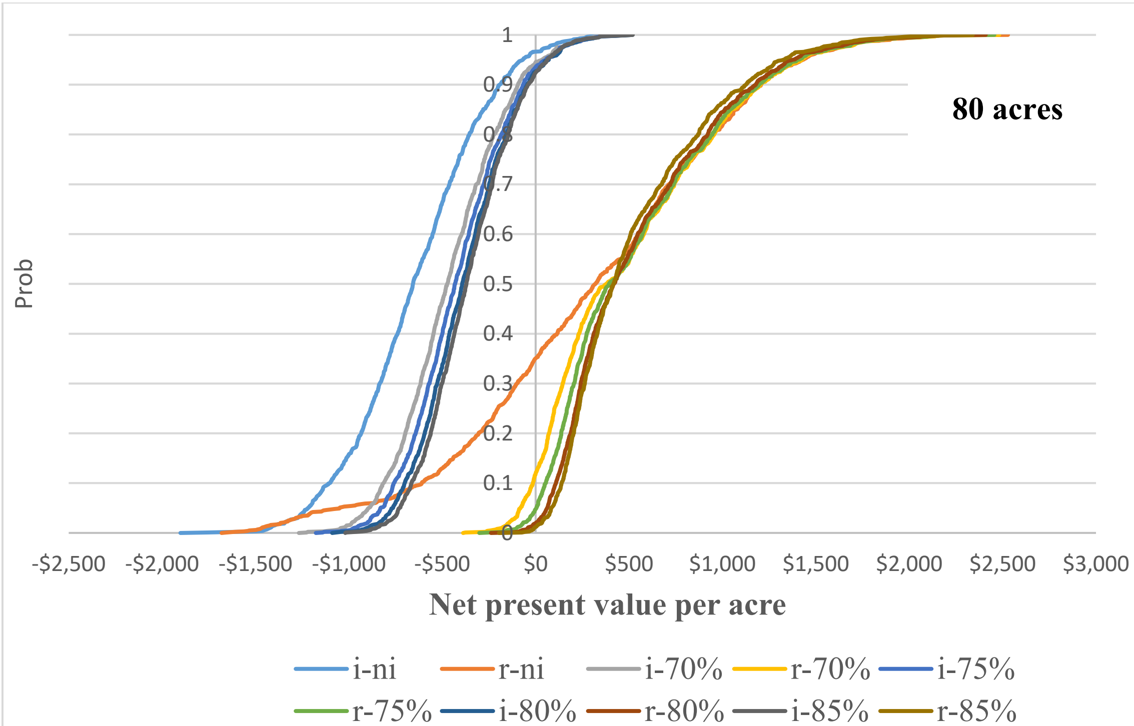

Figure B.3 CDF at 10% discount rate on 80 acre field size

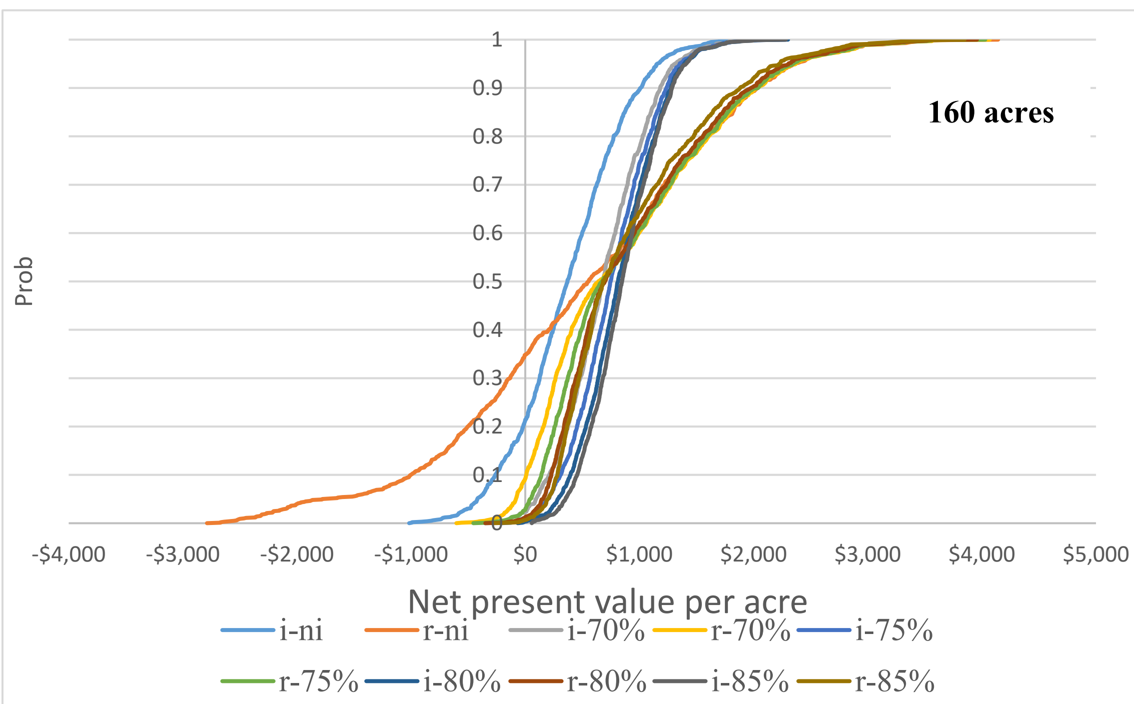

Figure B.4 CDF at 4% discount rate on 160 acre field size

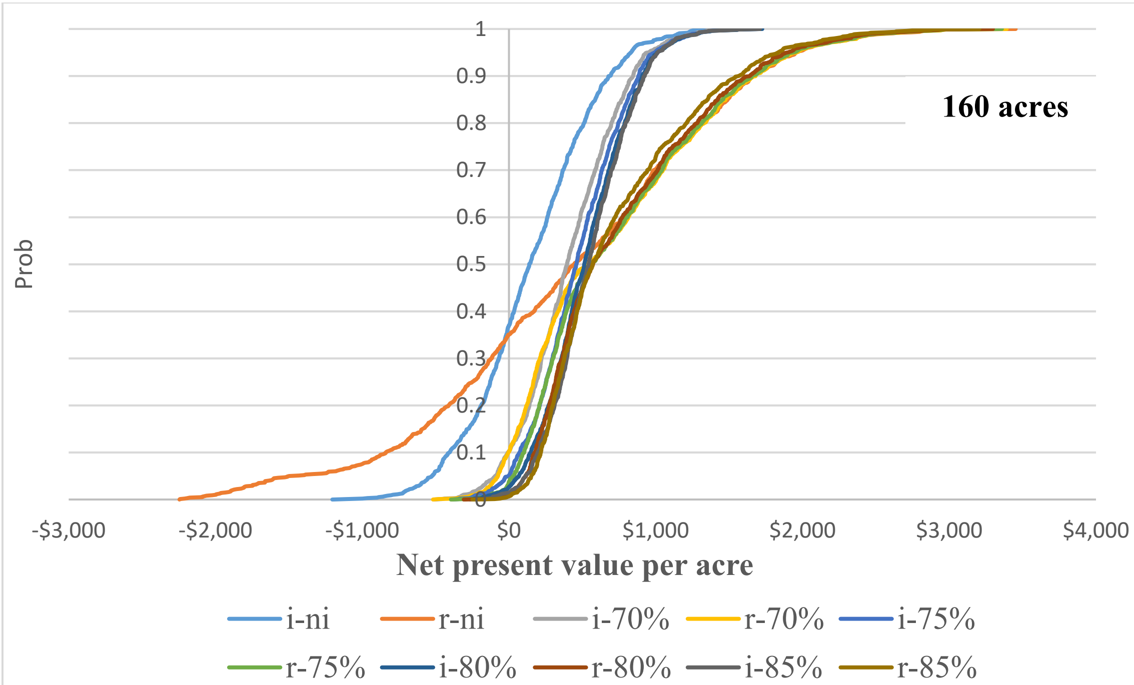

Figure B.5 CDF at 6% discount rate on 160 acre field size

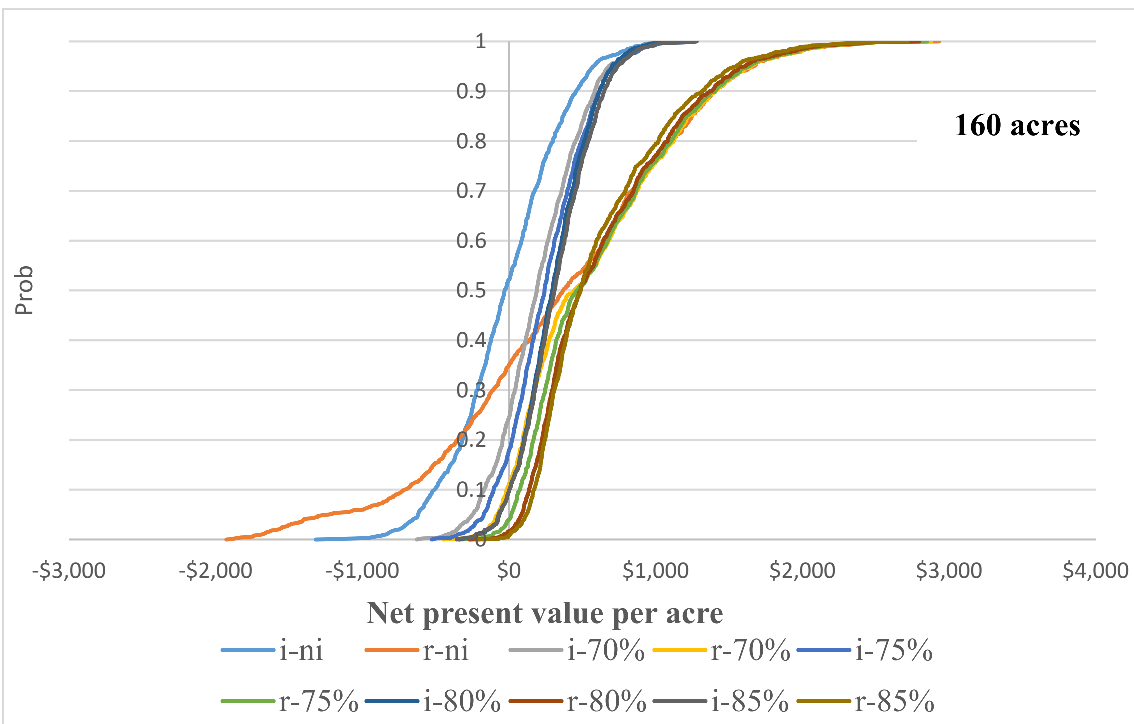

Figure B.6 CDF at 10% discount rate on 160 acre field size

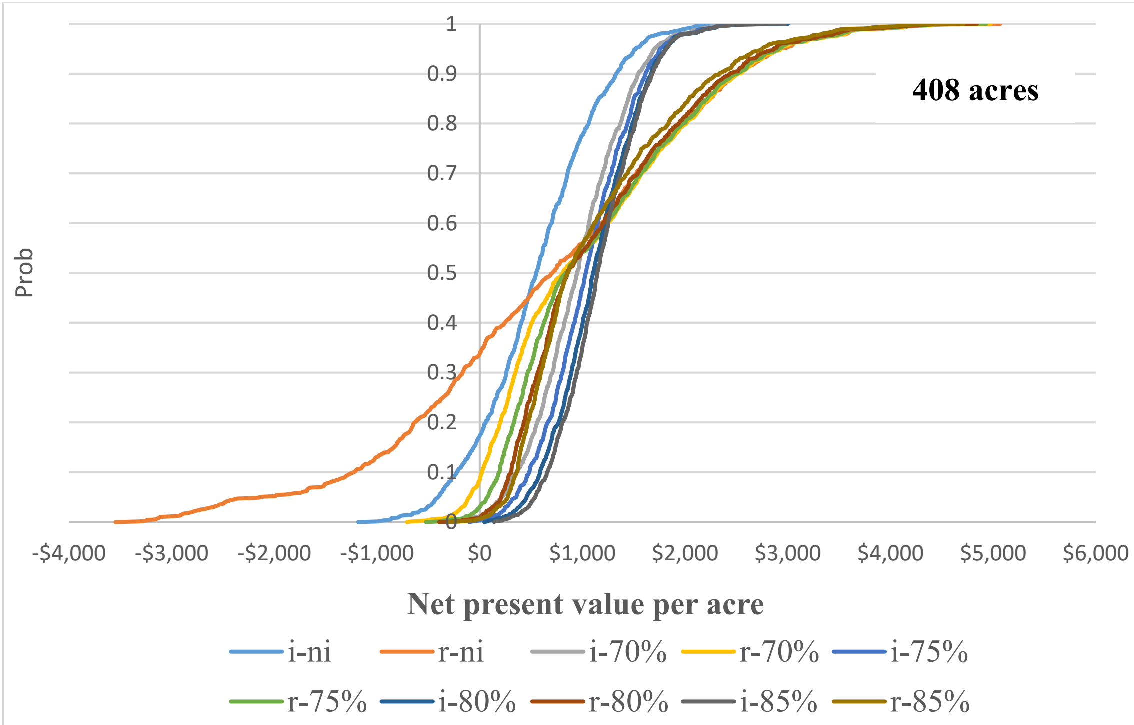

Figure B.7 CDF at 2% discount rate on 408 acre field size

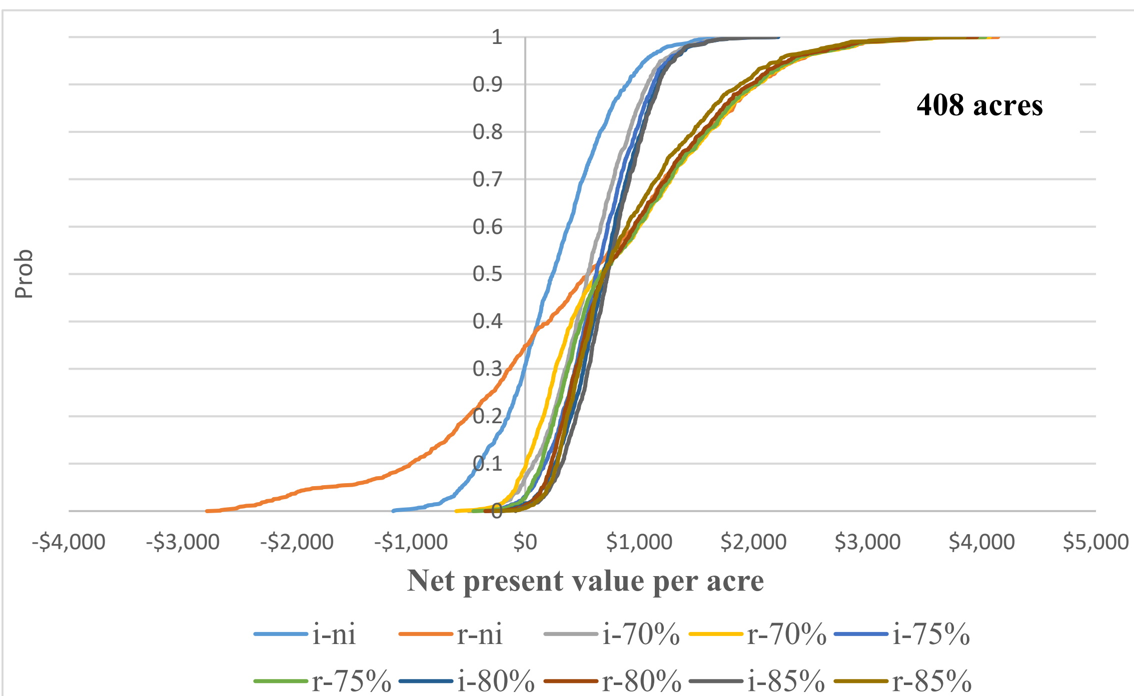

Figure B.8 CDF at 4% discount rate on 408 acre field size

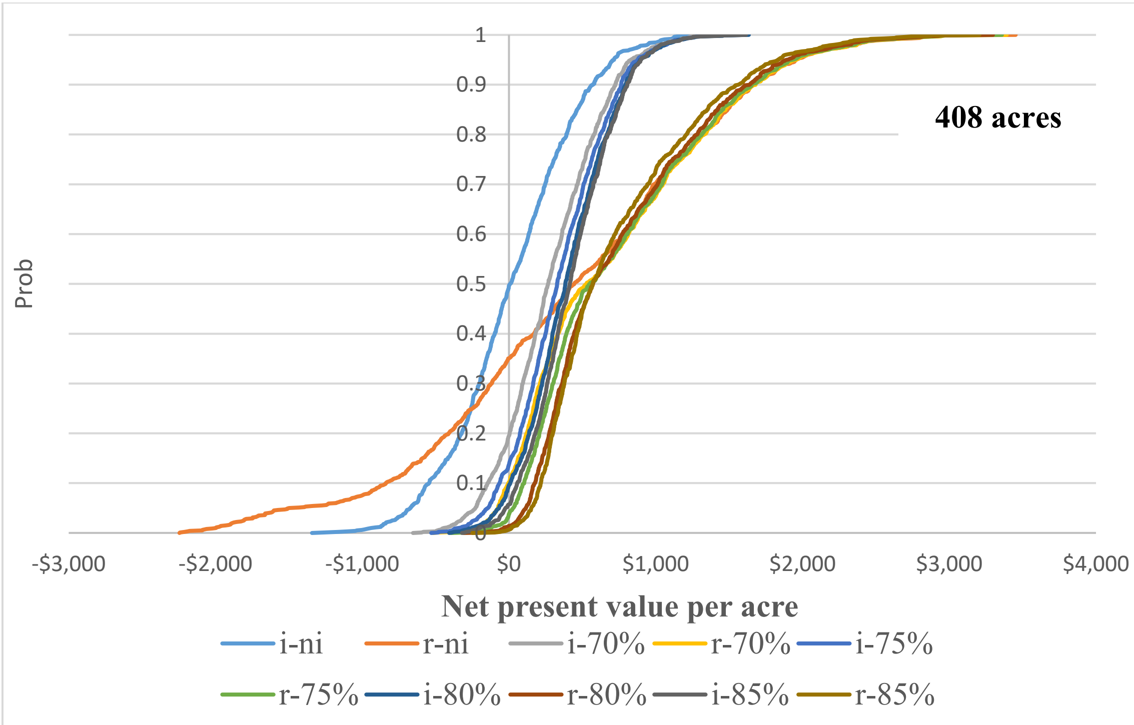

Figure B.9 CDF at 6% discount rate on 408 acre field size

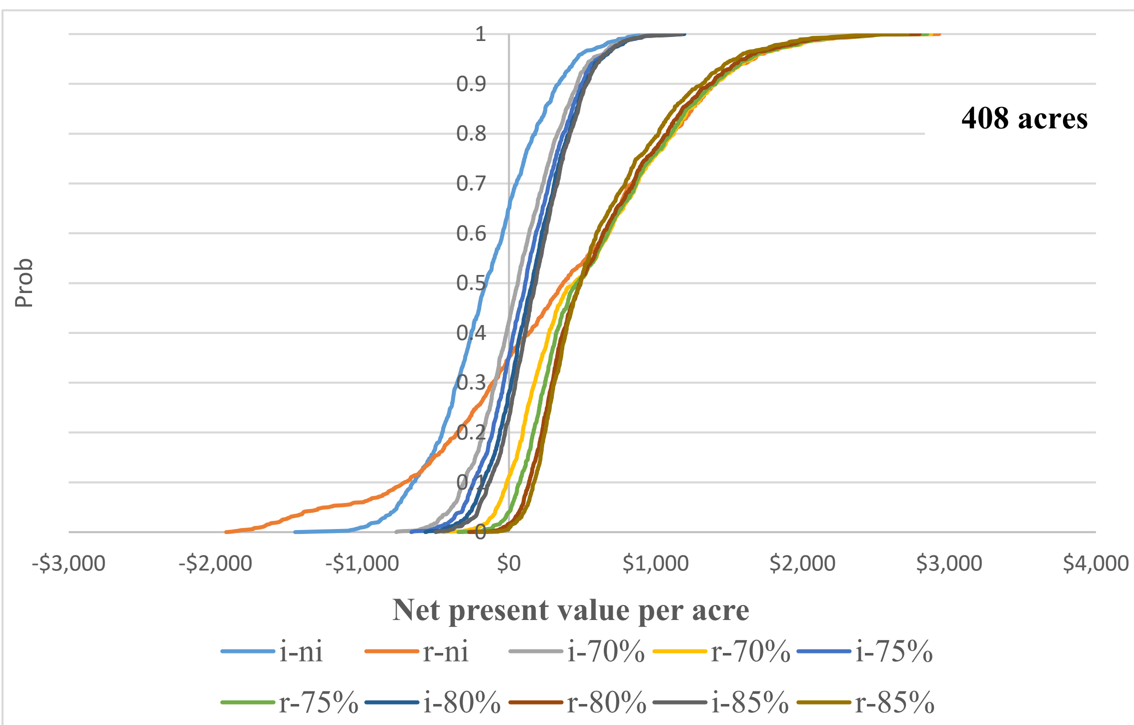

Figure B.10 CDF at 8% discount rate on 408 acre field size

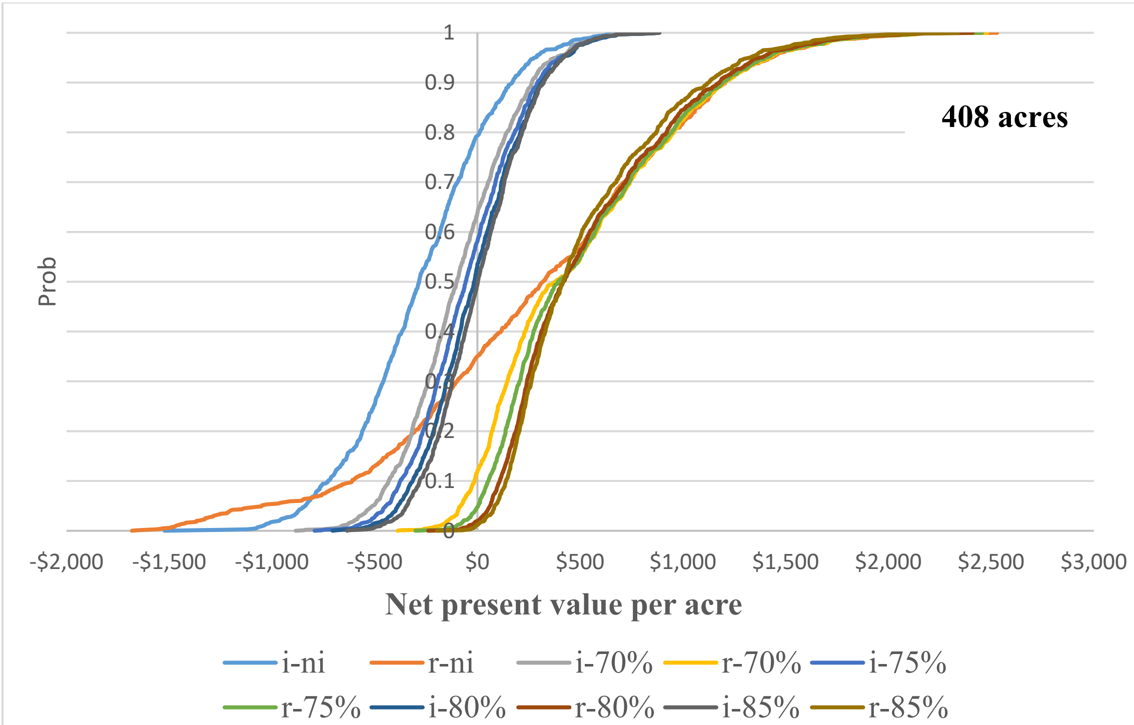

Figure B.11 CDF at 10% discount rate on 408 acre field size

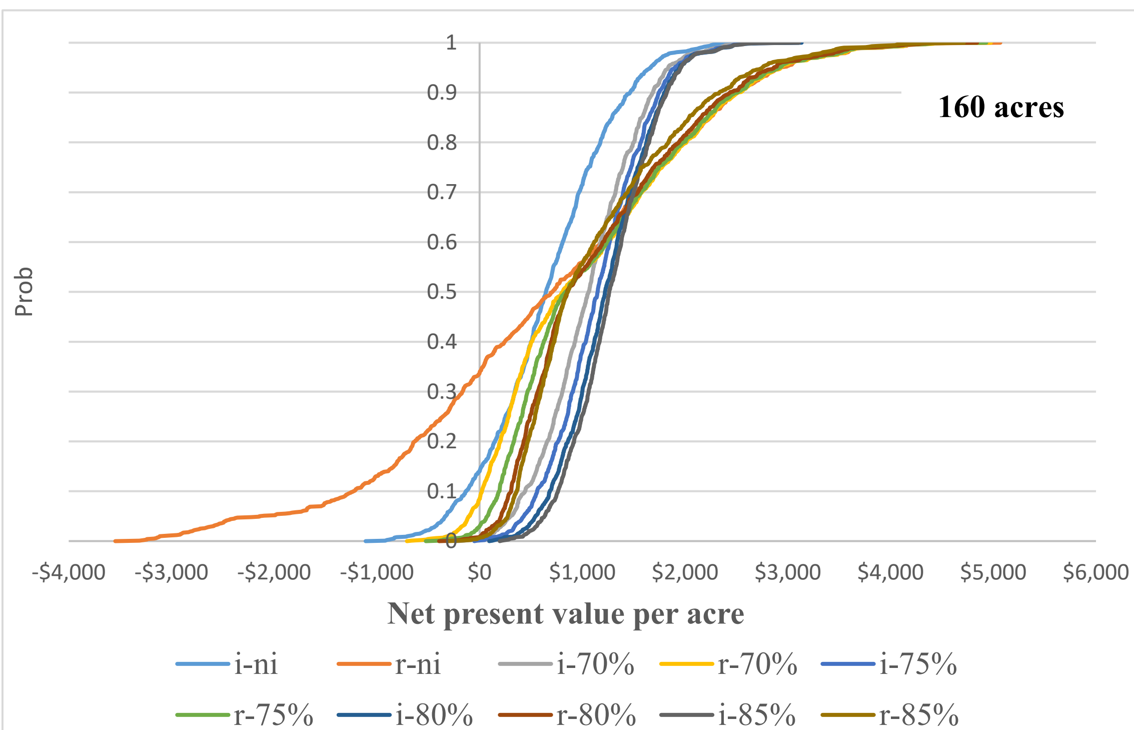

Figure B.12 CDF at 2% discount rate on 160 acre field size (financing investment)

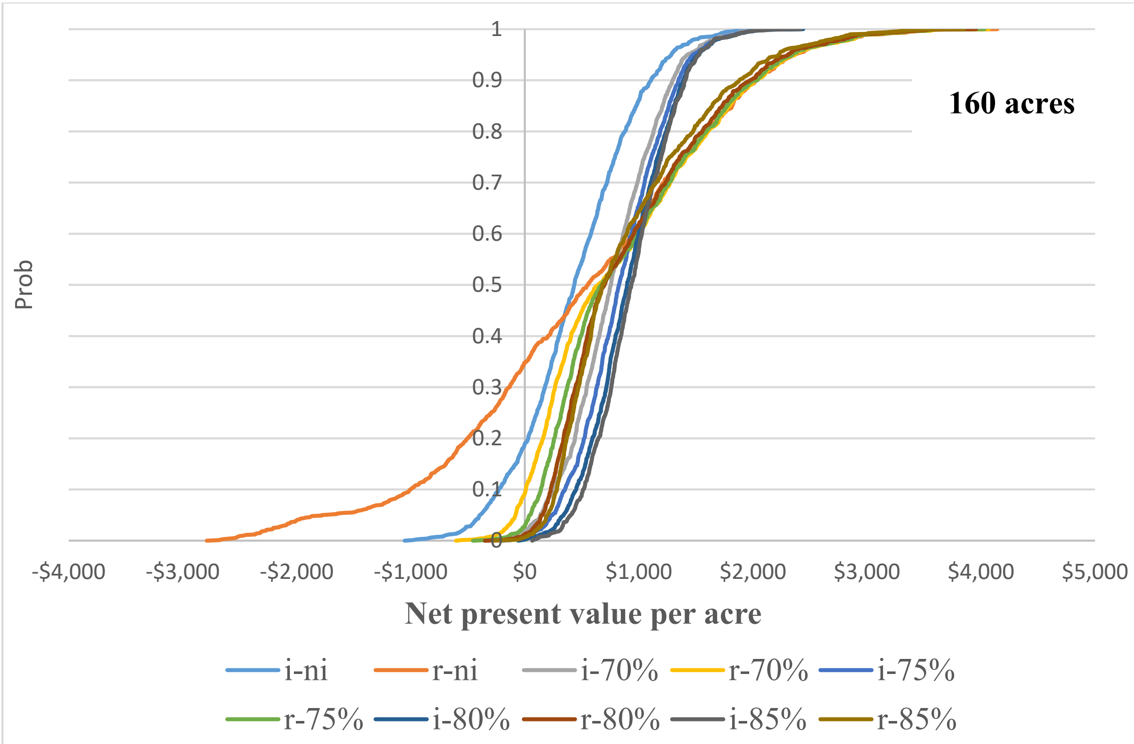

Figure B.13 CDF at 4% discount rate on 160 acre field size (financing investment)

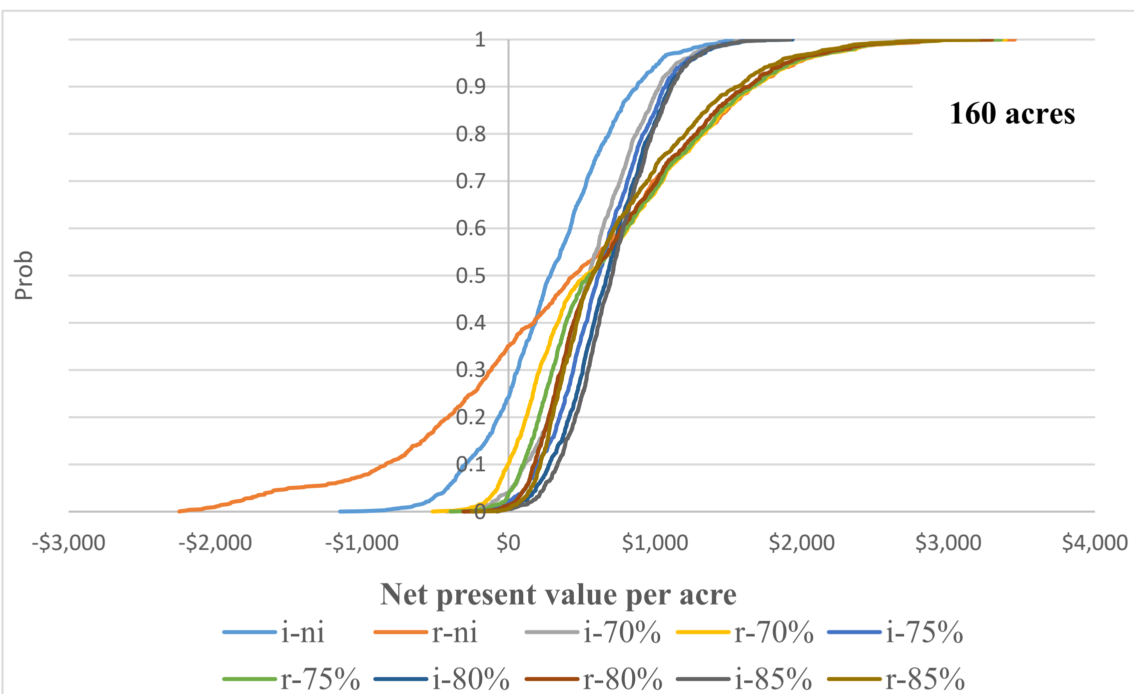

Figure B.14 CDF at 6% discount rate on 160 acre field size (financing investment)

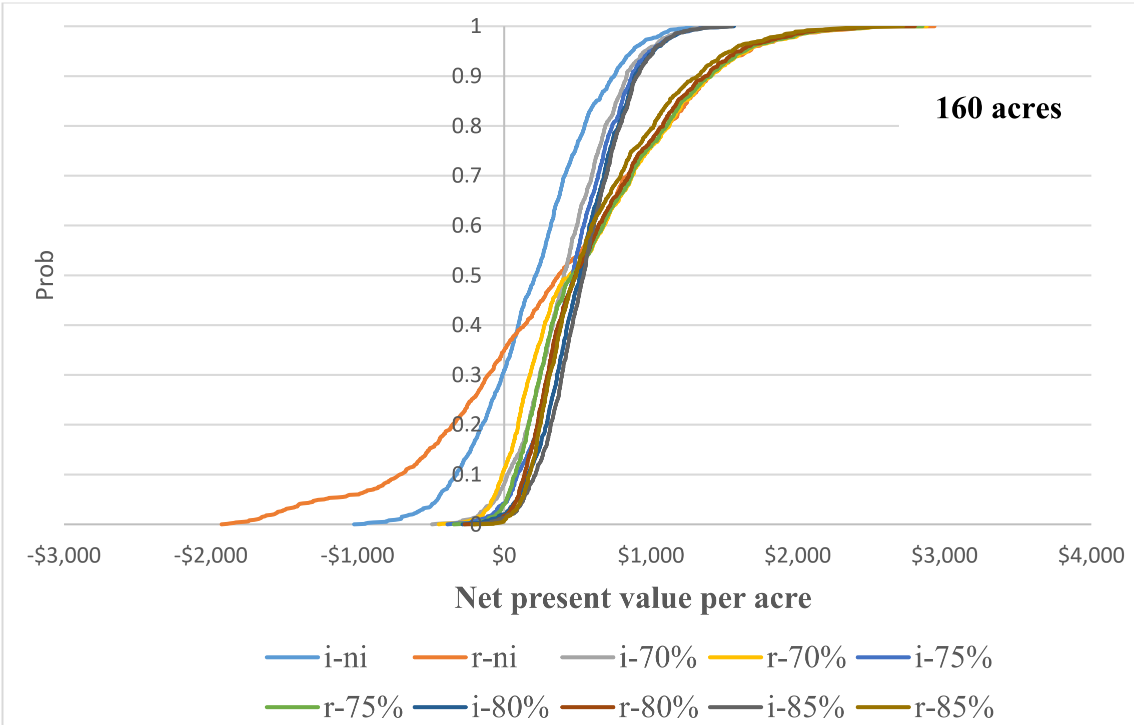

Figure B.15 CDF at 8% discount rate on 160 acre field size (financing investment)

APPENDIX C

STOCHASTIC EFFICIENCY WITH RESPECT TO A FUNCTION (SERF) ANALYSIS FOR ALTERNATIVE SCENARIOS

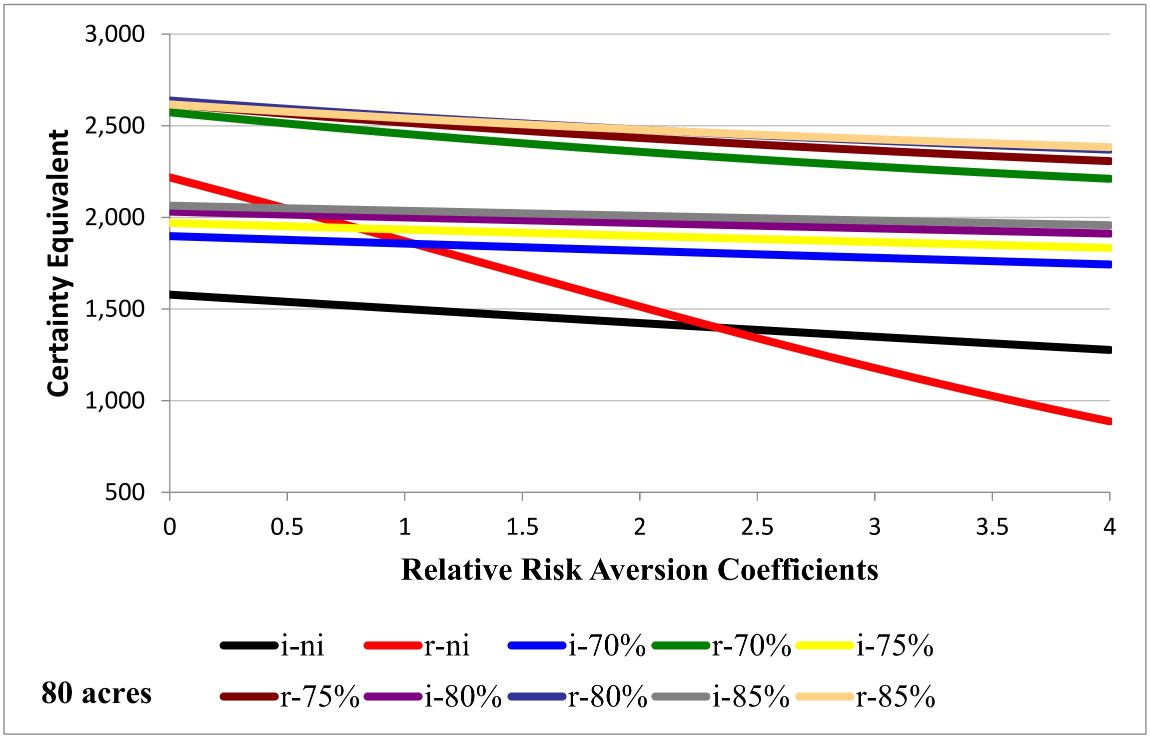

Figure C.1 SERF at 4% discount rate on 80 acre field size

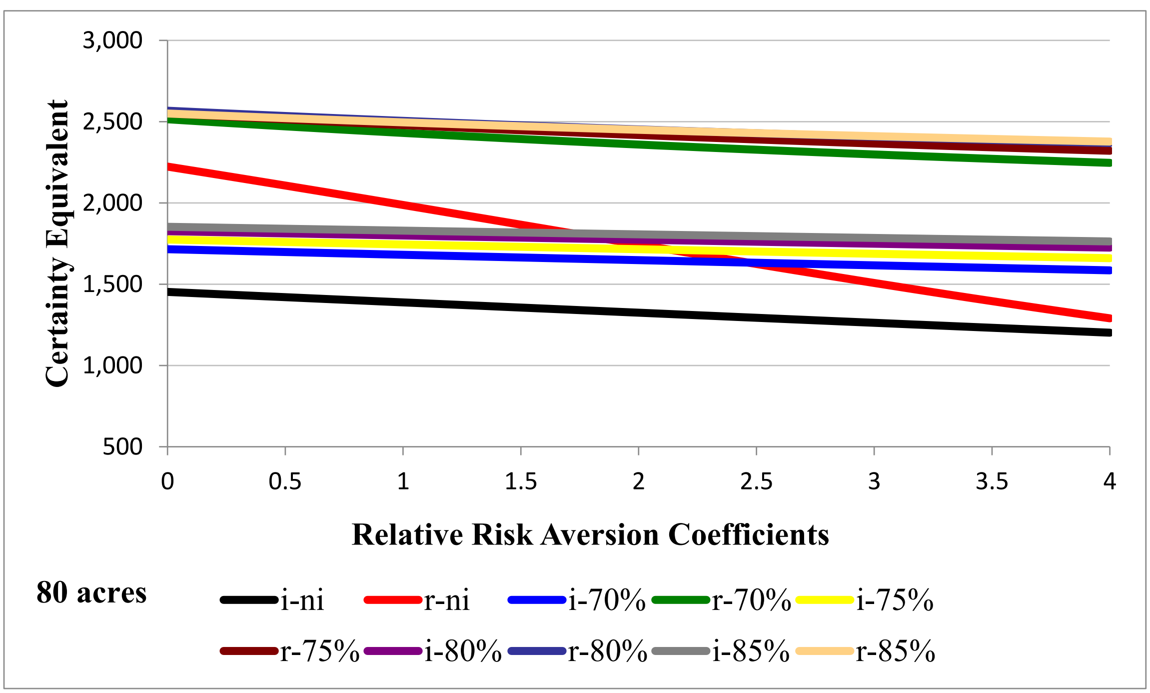

Figure C.2 SERF at 6% discount rate on 80 acre field size

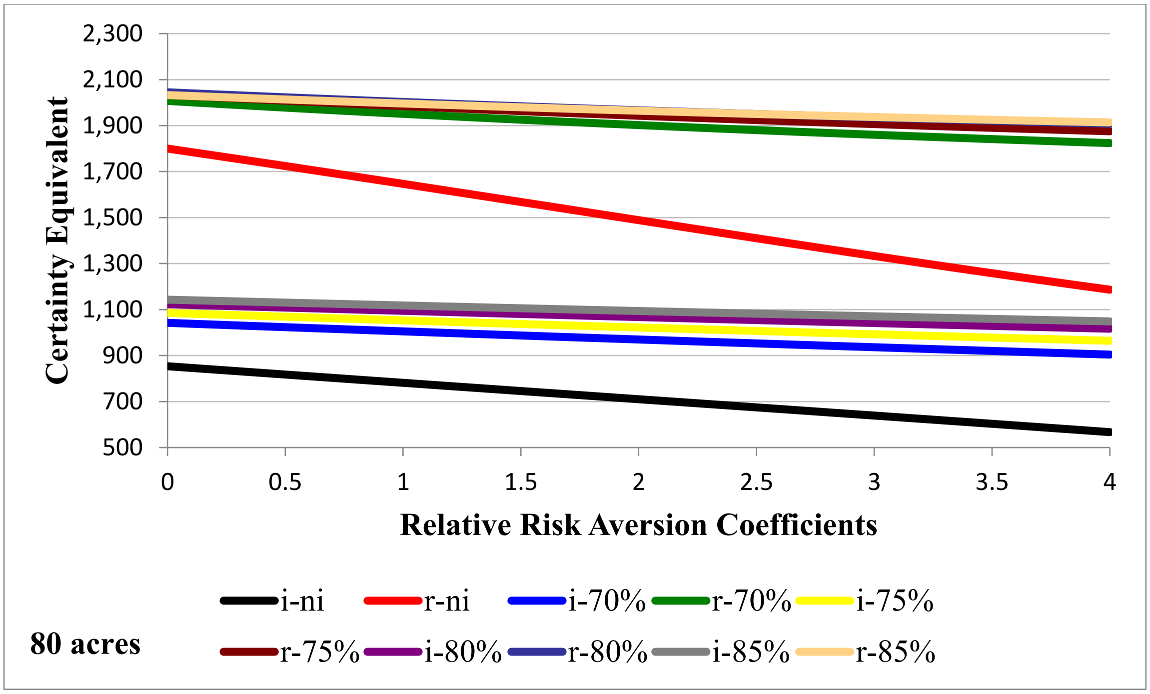

Figure C.3 SERF analysis at 10% discount rate on 80 acre field size

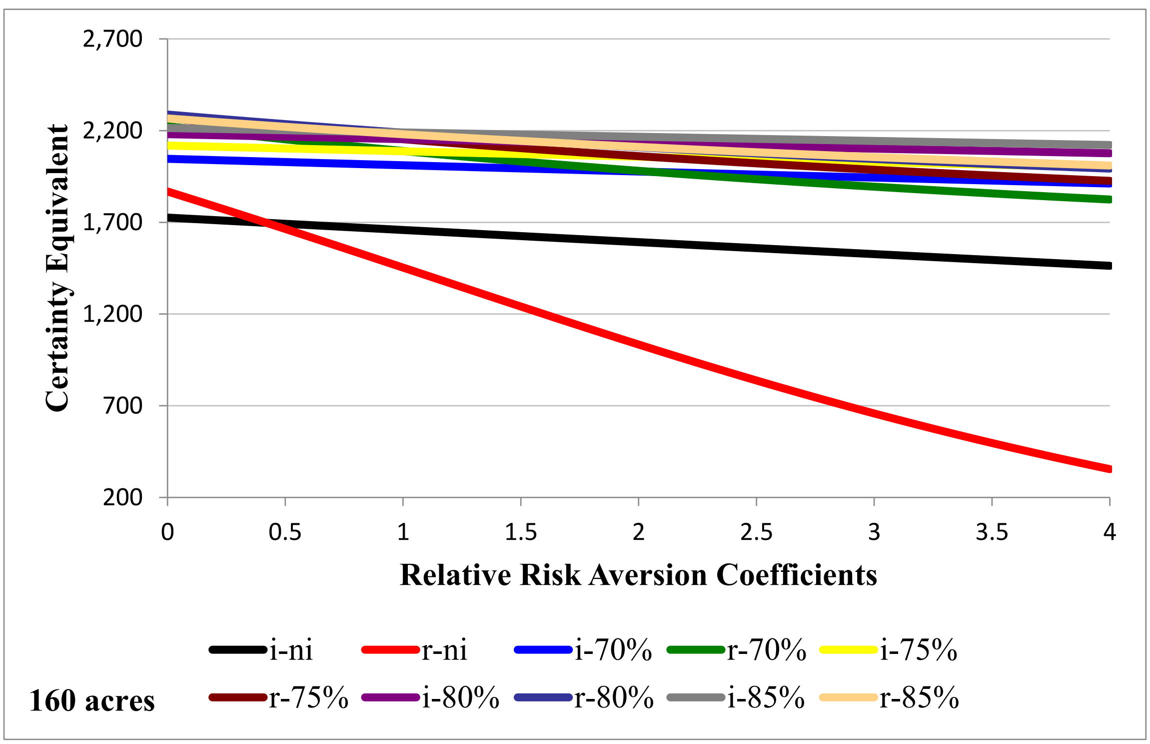

Figure C.4 SERF analysis at 4% discount rate on 160 acre field size

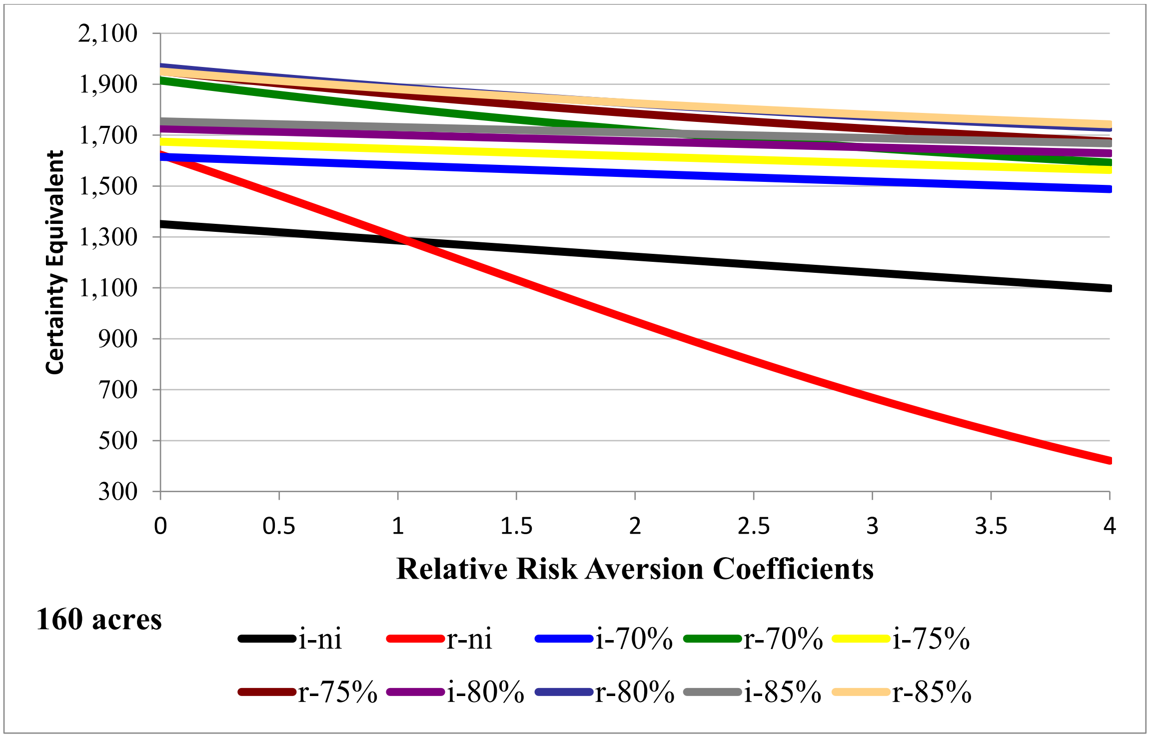

Figure C.5 SERF analysis at 6% discount rate on 160 acre field size

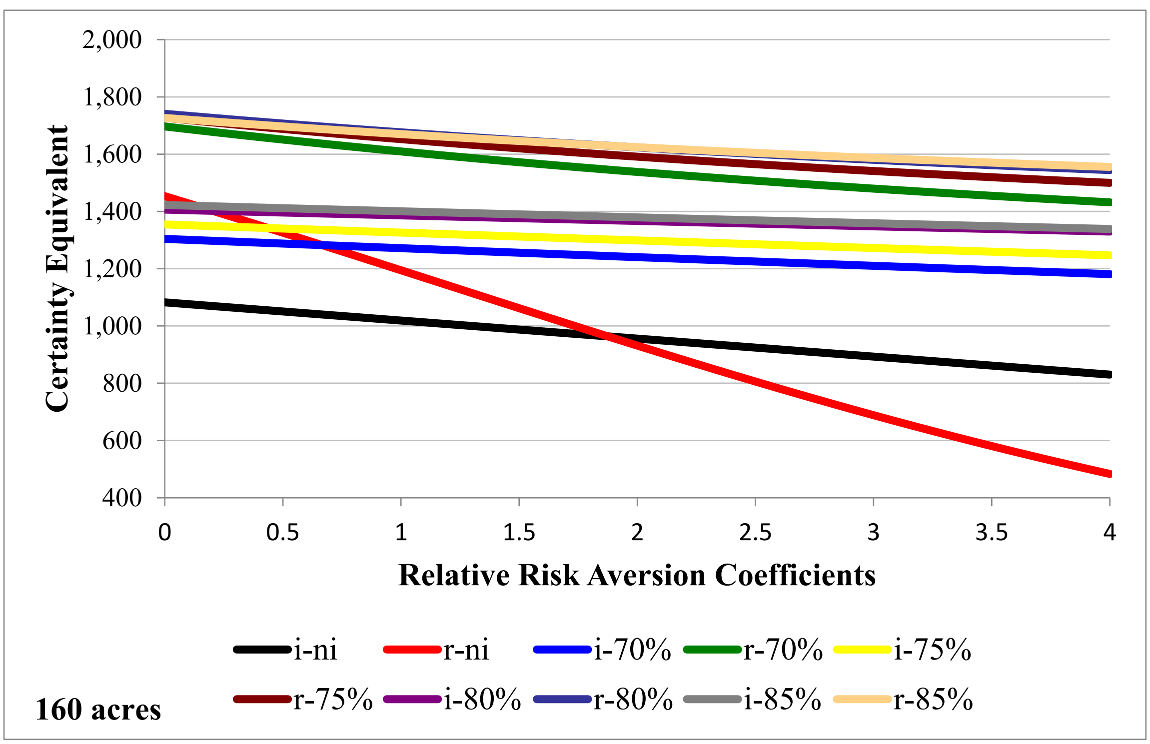

Figure C.6 SERF analysis at 8% discount rate on 160 acre field size

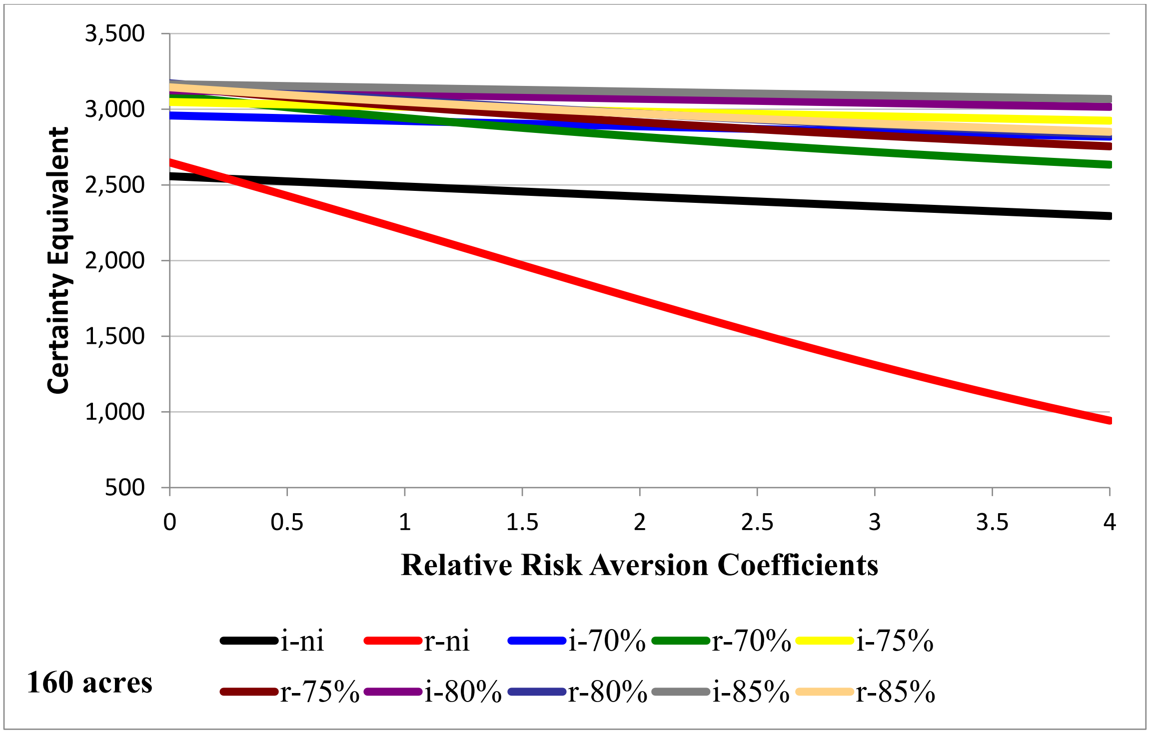

Figure C.7 SERF analysis at 2% discount rate on 408 acre field size

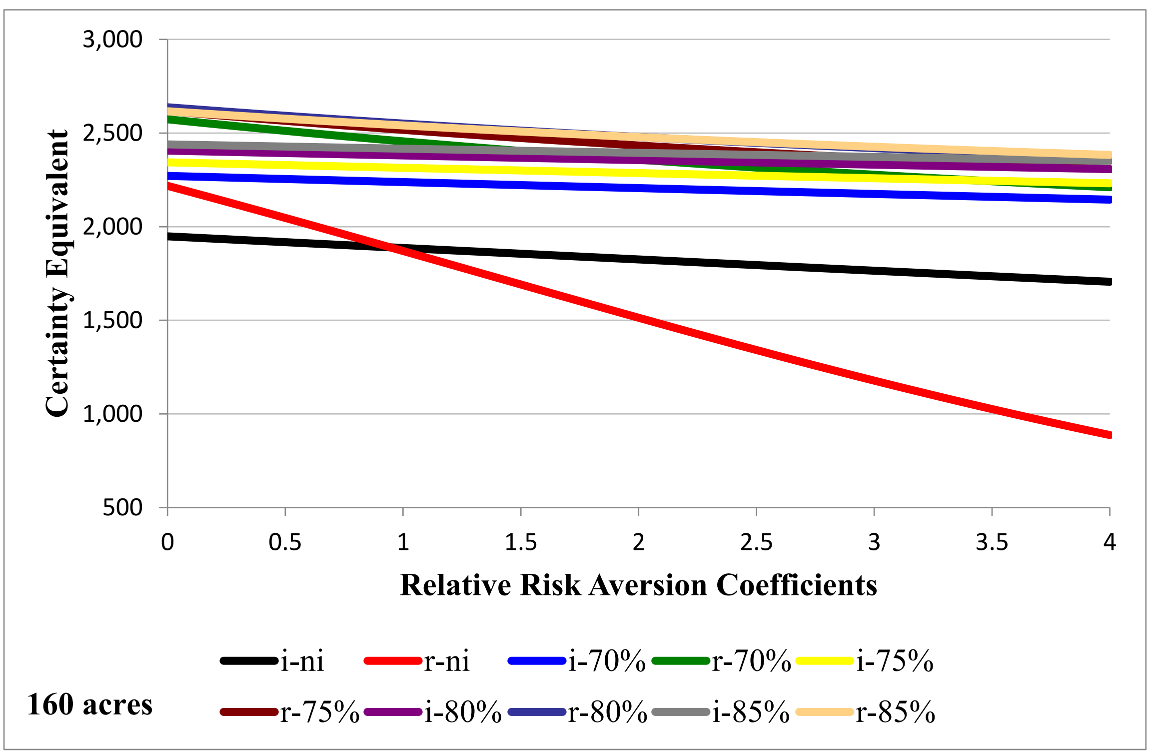

Figure C.8 SERF analysis at 4% discount rate on 408 acre farm size

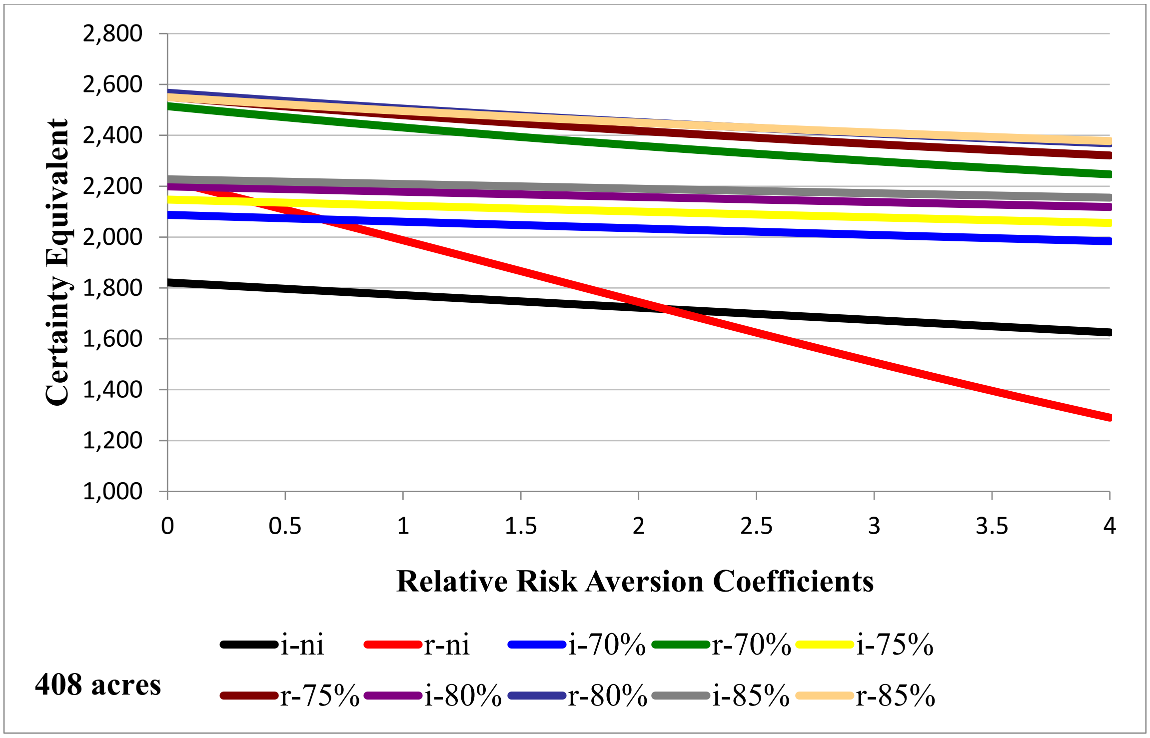

Figure C.9 SERF analysis at 6% discount rate on 408 acre field size

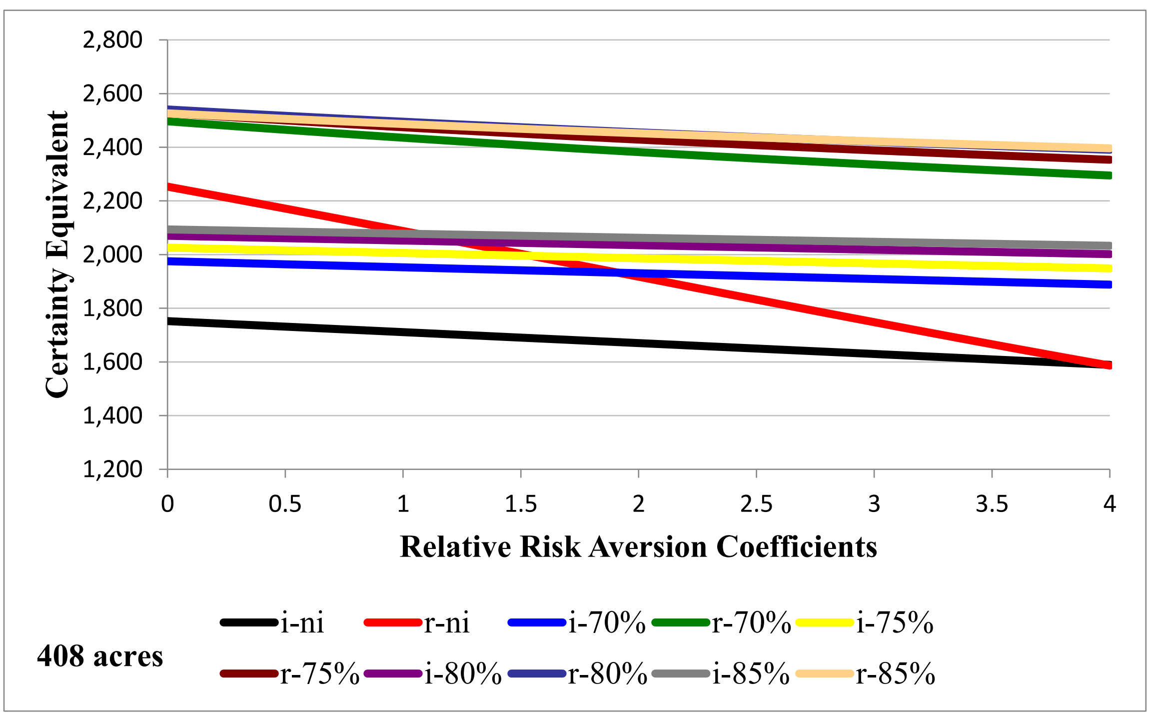

Figure C.10 SERF analysis at 8% discount rate on 408 acre field size

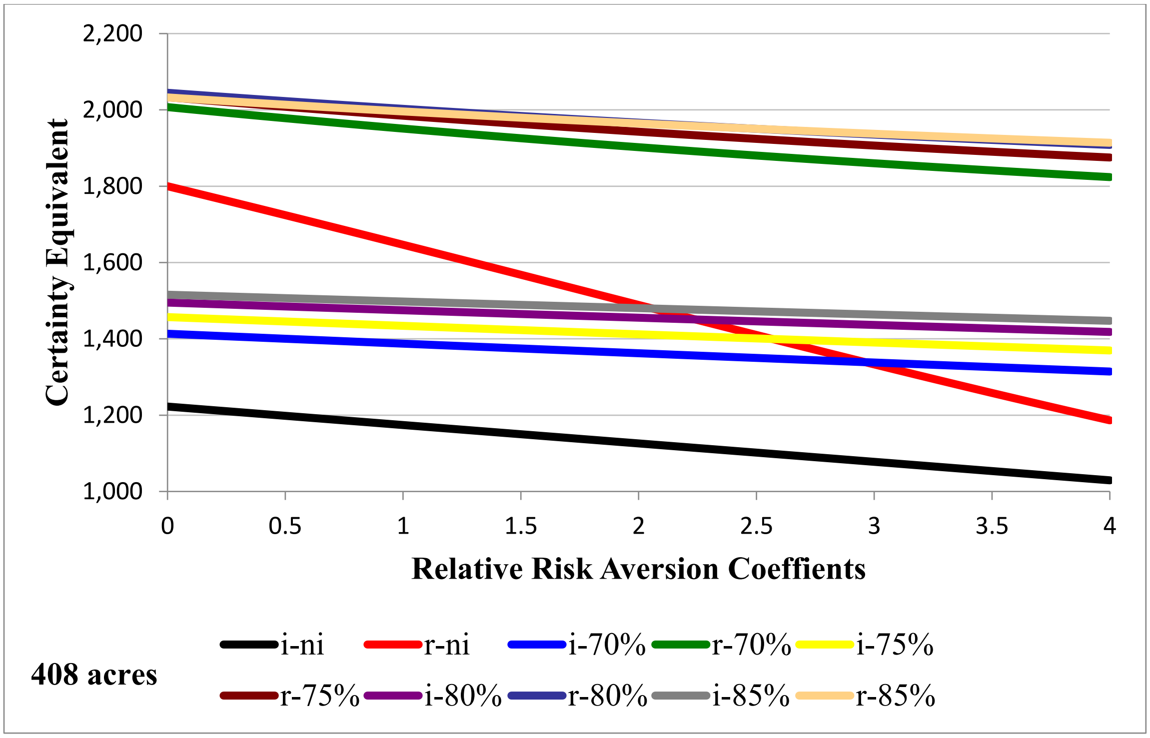

Figure C.11 SERF analysis at 10% discount rate on 408 acre field size

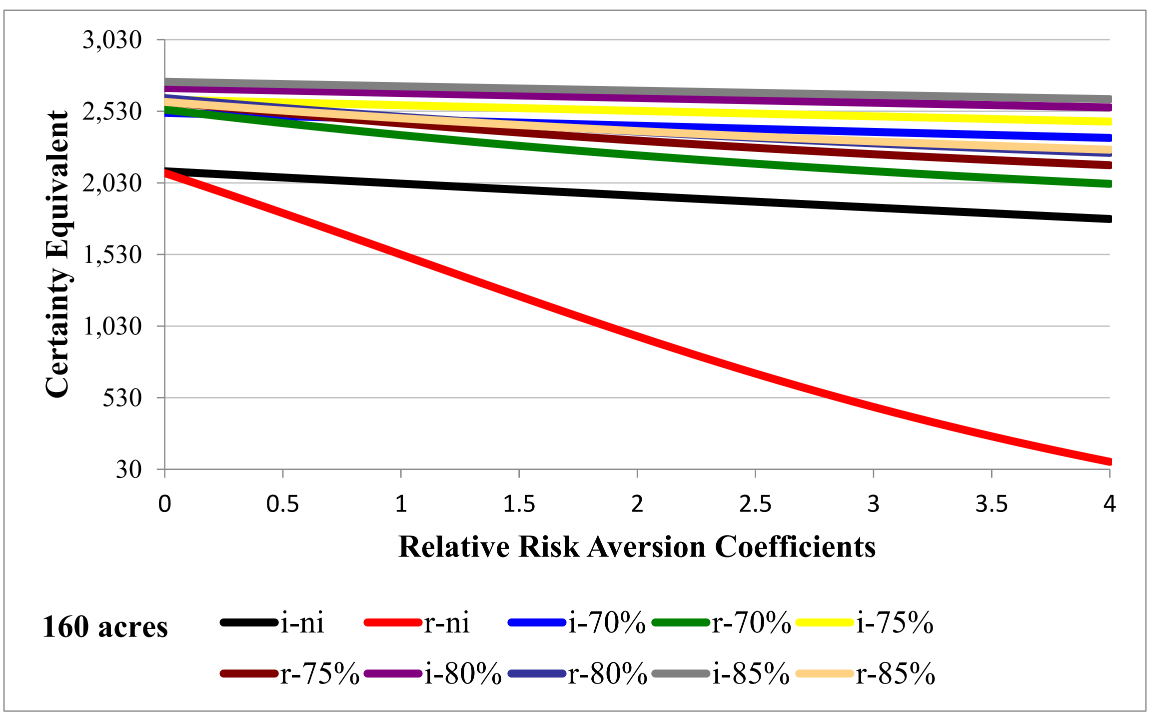

Figure C.12 SERF analysis at 2% discount rate on 160 acre field size (financing investment)

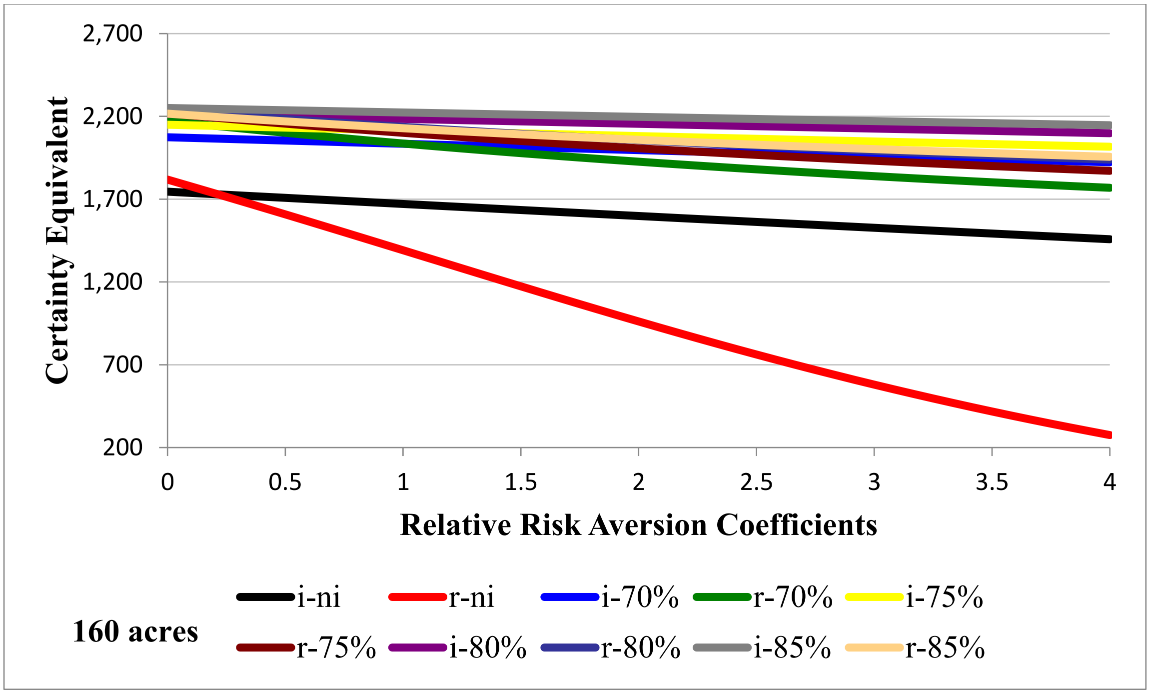

Figure C.13 SERF analysis at 4% discount rate on 160 acre field size (financing investment)

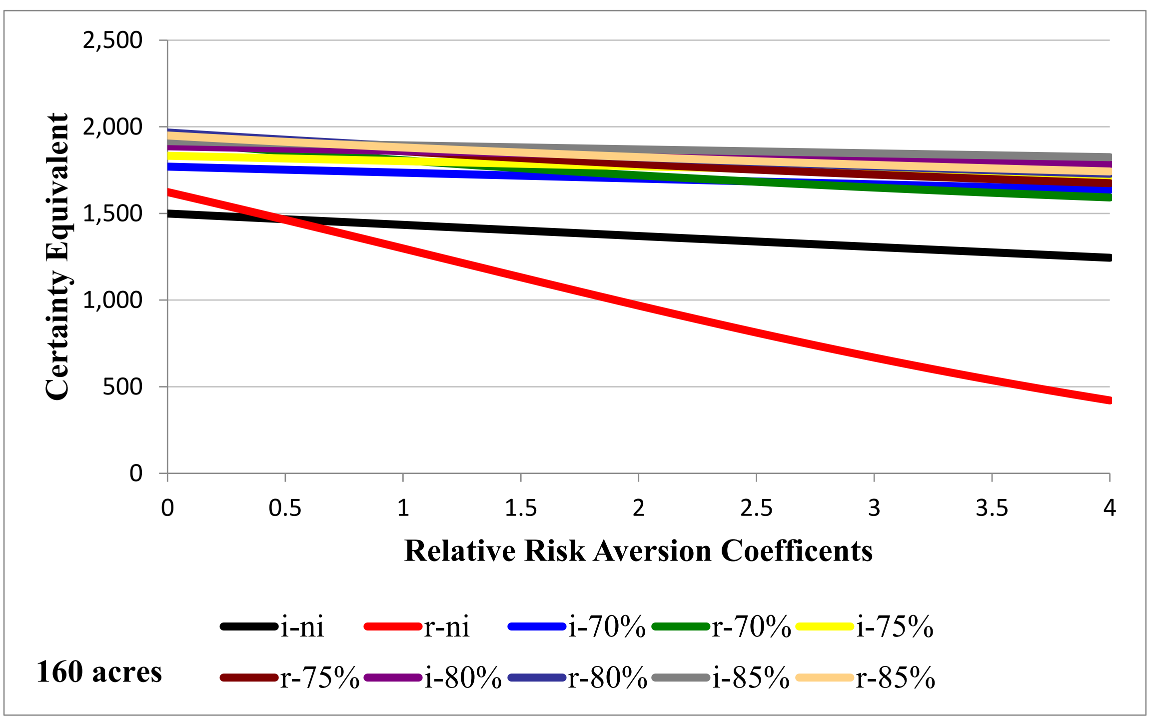

Figure C.14 SERF analysis at 6% discount rate on 160 acre field size (financing investment)

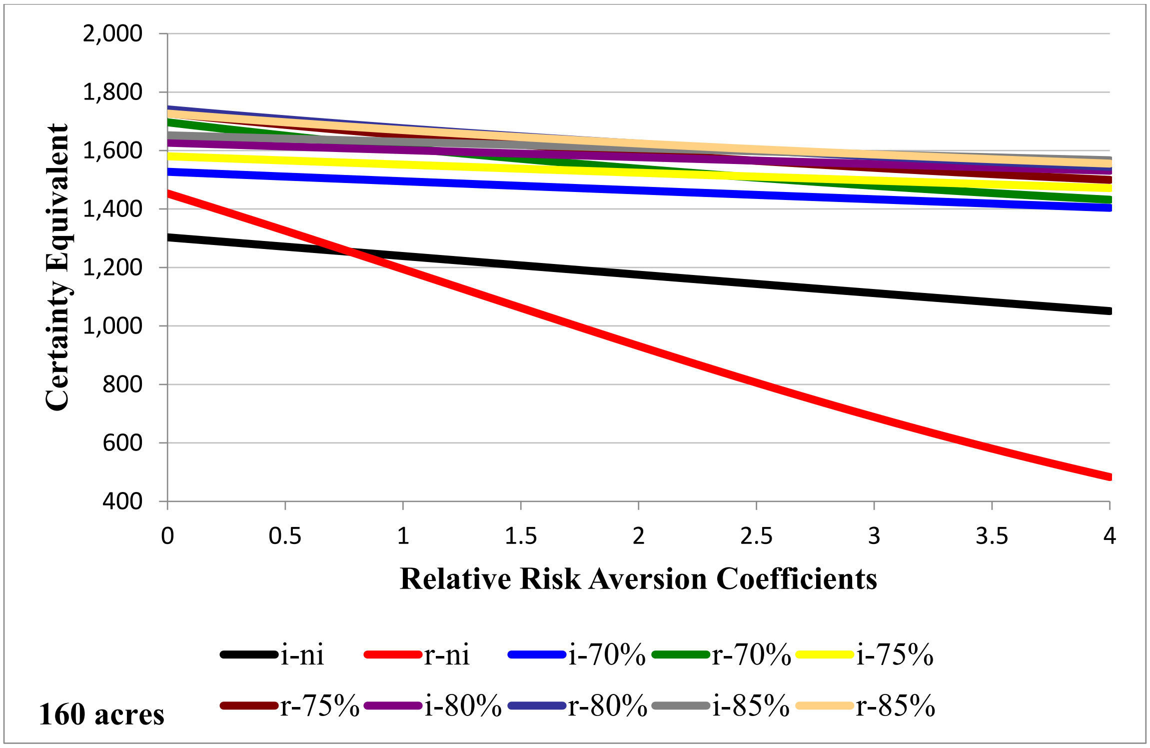

Figure C.15 SERF analysis at 8% discount rate on 160 acre field size (financing investment)

APPENDIX D

AVERAGE COST OF PRODUCTION FOR NON-DELTA AREAS

Table D.1 Average estimates for soybean production per acre

ITEMS	Units	Quantity	price	Estimates based on total amounts used ($/acre)
Fertilizer				38.4
herbicides and insecticides				105.3
other direct expenses				102
Operator Labor				
Tractors	hour	13.4	0.312	4.1
Harvesters	hour	13.4	0.1021	1.34
Irrigation Labor	acre/in	0.06	6	0.36
Hand Labor				
Implements	hour	9.06	0.105	0.95
Unallocated Labor	hour	13.11	0.3731	4.9
Diesel Fuel				
Tractors	gal	1.7	3.052	5.2
Harvesters	gal	1.7	1.3935	2.4
Repair & Maintenance				
Implements	acre	4.69	1	4.69
Tractors	acre	1.81	1	1.81
Harvesters	acre	3.44	1	3.44
Interest on op. cap.	acre	9.49	1	7.04
Fixed Expenses				
Implements	acre	9.14	1	9.14
Tractors	acre	11.45	1	11.45
Harvesters	acre	13.56	1	13.56

Source: MSU Extension planning budget for Non-Delta area

Table D.2 Average estimates for corn production per acre

ITEMS	Units	Quantity	price	Estimates based on total amounts used ($/acre)
Fertilizer				60.2
herbicides and insecticides				123.60
other direct expenses				155.1
Operator Labor				
Tractors	Hour	13.4	0.4823	6.34
Harvesters	Hour	13.4	0.01277	0.17
Irrigation Labor	acre/in	0.06	6	0.36
Hand Labor				
Implements	Hour	9.06	0.1442	1.31
Unallocated Labor	Hour	13.14	0.01277	0.17
Diesel Fuel				
Tractors	Gal	1.7	3.645	6.2
Harvesters	Gal	1.7	1.742	2.96
Repair & Maintenance				
Implements	Acre	8.56	1	8.56
Tractors	Acre	2.56	1	2.56
Harvesters	Acre	4.30	1	4.30
Interest on op. cap.	Acre	10.43	1	10.43
Fixed Expenses				
Implements	Acre	9.67	1	9.67
Tractors	Acre	13.95	1	13.95
Harvesters	Acre	16.95	1	16.95

Source: MSU Extension planning budget for Non-Delta area

Table D.3 Cost of irrigation reservoir based on farm acreage

Acreage	80	160	408
Irrigation Reservoir	\$34,117.5	\$68,235	\$145,000
Center Pivot Irrigation System	\$84,000	\$84,000	\$302,000
Total Cost	\$118,117.5	\$152,235	\$447,000