On-Farm Water Storage (OFWS) as a Tool to Reduce Risk

Domena Agyeman
M.S Student
Department of Agricultural Economics
Mississippi State University
daa205@msstate.edu

Brian Williams
Assistant Professor
Department of Agricultural Economics
Mississippi State University

Keith Coble
Professor
Department of Agricultural Economics
Mississippi State University

Bryon Parman
Assistant Professor
Department of Agricultural Economics
Mississippi State University

Mary Love Target
Assistant Professor
Department of Agricultural and Biological Engineering
Mississippi State University

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Abstract

Though irrigation can offer producers many advantages such as reducing potential losses due to uncertain rainfall, in some areas of the Southeast irrigation options for agricultural crops are limited. For example, in East Mississippi access to groundwater resources is impractical, with well depths often exceeding 1,000 feet and prohibitively high drilling costs. As a result, producers are gradually resorting to the use of on-farm water storage systems (OFWS) to recapture irrigation runoff and rainfall for later use for irrigation. Previous research has confirmed reduced groundwater withdrawal and downstream flow of nutrients are some advantages that come with OFWS, but few studies have focused on the economic profitability of this system. This article employs a stochastic benefit-cost analysis to analyze the net returns of irrigating from an OFWS 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 and yields. Preliminary findings indicate that investing in an OFWS for irrigating purposes can increase producers returns significantly compared to depending on rainfall. As expected increase in interest rates reduces the net present value of making such an irrigation investment and this is more evident when interest are above 7%. The use of OFWS becomes more attractive when revenue generated is protected under crop insurance. As coverage levels increases the net present value of investing in an OFWS increases well above that rain-fed production at lower interest rates, however there's over 60% chance of rain-fed production been more profitable than irrigating at 70%, 75%, 80% and 85% coverage levels when discount rates are over 9%.

Keywords: On-Farm Water Storage, Prices, Yield, Risk

Introduction

With 70 percent of the world's annual consumption, agriculture is undoubtedly the largest consumer of the world's fresh water. Presently, irrigation agriculture accounts for 40 percent of global food production from 20 percent of cultivated land (FAO, 2014). Current predictions indicates an average annual increase of 0.6 percent in irrigated land until 2030 (UNESCO-WWAP, 2016). In 2005, O'Neill and Dobrowolski reported that farmers over the world are irrigating five times more land area than they did in the 20th century. This rise in irrigated agriculture can be related to the fact that yields and profit from irrigated fields are higher (UNESCO-WWAP, 2012; Evett, Carman, and Bucks, 2003) and more consistent (Dowgert, 2010) compared to that of rain-fed agriculture.

In 2012, USDA-NASS reported 55.8 million acres of irrigated land in the US. The crops with the most land irrigated are corn for grain (13.3), soybeans for beans (7.4), and alfalfa (5.5) all in millions per acres (USDA-NASS, 2012). With 1.7 million acres of land under irrigation, Mississippi is ranks 9th in irrigation. In 2012, soybean and corn received the most irrigation in Mississippi with 863,200 and 425,872 acres irrigated respectively (NASS, 2012). Mississippi crop producer's dependence on supplemental irrigation to boost production, especially during low rainfall periods, has increased due to the increase in uncertainty of rainfall distributions (Kebede et al, 2014; Sassenrath et al., 2013). But, access to reliable sources of water for irrigation, especially during dry seasons, remains a challenge for producers. The concern about reliable sources of water stems from the fact that groundwater has long been the main source of irrigation water, but the frequent withdrawal from this source has led to the depletion of several natural aquifers (Konikow, 2013). Though natural aquifers are a renewable resource due to seasonal influx of rainfall, the natural recharge of this resource is not sufficient to meet growing demands from groundwater withdrawals (Bouldin et al., 2004).

The Mississippi River Alluvial Aquifer has reduced substantially in groundwater levels since the 1970's at an annual rate of about 100,000 acre-feet due to the increase in irrigated acres (Kiemeyer III et al., 2012). To mitigate similar declines in groundwater levels, authorities in some states had to implement drilling moratoriums. For example, in 1986 New York established a moratorium that prevented new approvals to either drill new wells into or withdraw water from the Lloyd aquifer. In 2001, a ban was placed on drilling new wells in Pumpkin Creek Basin Sub-area in Nebraska. Similar moratoriums have been implemented in states such as California, Florida and Georgia to mention a few. Although there are no such bans on drilling wells in Mississippi, concerns about groundwater declines over the years can draw the attention of authorities to implement drilling moratoriums, which will consequently reduce water accessibility for irrigation in some regions of the state. In areas such as East Mississippi where irrigation is impractical, crop producers have to drill over 1000 feet to gain access to enough groundwater for irrigation. This, coupled with only 30 percent of annual rainfall occurring in growing periods (Kebede et al., 2014), makes it difficult for producers in East Mississippi to meet their production goals especially during less rainfall periods.

To supplement rainfall sufficiently with irrigation, producers and investors in Mississippi have resorted to the use of on-farm water storage systems (OFWS) for both economic and conservation purposes (Ouyang et al., 2015; Moore, Pierce and Farris, 2015; Boulden et al, 2014; Kimmerer III et al., 2012). This alternative is also anticipated to ensure constant availability of water if drilling moratoriums are implemented in Mississippi in the future. OFWS involves capturing and holding water onsite that might ordinarily be lost through run-off or in-stream flow and making it available for later use for irrigation. More OFWS have been constructed in recent years in Mississippi (Ouyang et al., 2015; Moore, Pierce and Farris, 2015) which is an indicator of its growing acceptance in the region. Though the system has shown its advantages by saving significant amount of water from groundwater resources (Ouyang et al., 2015) and reducing nutrient loss to downstream flow through rainfall and irrigation runoff from agricultural fields (Tagert et al., 2014; Kirmeyer III, et al.. 2012; Fierner et al., 2005; Bouldin et al., 2004), the lack of economic feasibility studies to assess the profitability and riskiness of using the system could deter potential producers and investors from investing in the system due to its high initial investment cost.

Most studies concerning the use of OFWS in Mississippi have concentrated on quantifying the amount of nutrients saved from flowing downstream and determining the desirable pond size ratio to supply sufficient irrigation water (Ouyang et al., 2015) during the growing season. Few studies have been conducted to assess the profitability of the system. For example, no study has analyzed the overall cost and benefit of 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 focus on the economic feasibility of the system is Falconer, Lewis and Krutz, (2015). They estimated the net present value (NPV) of an OFWS with a Tailwater Recovery (TWR) system in the Mississippi Delta. Tailwater is surface runoff water from production land, whether from excessive irrigation or rainfall. TWR capture this surface water in a recovery ditch before is later pumped into the reservoir (Czarnecki, Omer and Dyer, 2016). Falconer, Lewis and Krutz, (2015) compared the NPV of estimated returns for corn and soybean from rain-fed, furrow irrigated production and center pivot irrigated productions. Their results showed that it is not economically viable for crop producer to the Delta region to invest in an OFWS due to its high initial cost and the land size needed for installation. Potential cost savings for recycled nutrients and other environmental benefits were not accounted for in the abovementioned study.

Wailes et al., (2003) used the Modified Arkansas off-stream Reservoir Analysis Model (MARORA) to estimate the economic feasibility of on-farm reservoir in eastern Arkansas. Findings showed that it is not economically sound to investment in an on-farm reservoir when groundwater levels are adequate; similar to results found by Popp et al., (2003). But returns can be increased by using a more efficient irrigation system. With relatively high groundwater levels in the Mississippi delta, this result can be used to explain the finding of Falconer, Lewis and Krutz, (2015). Boulden et al., (2004) used a cost-benefit ratio (BCR) and internal rate of return (IRR) approaches to analyze the economic feasibility of an OFWS with TWR and a well system. At an interest rate of twenty percent for the BCR ratio analysis, findings from their study shows that the economic benefits of using both systems exceed the cost involved. This was attributed to the ecological services, decreased nutrients to waterways, top soil saved and other merits that come with the relift system.

Apart from reducing groundwater withdrawal, researchers have shown that OFWS have the potential to trap and store potential contaminants (fertilizer, pesticides, herbicides, crop residues, etc.) that threaten the water quality of nearby water bodies. (Moore, Pierce and Farris, 2015; Paz, 2012; Target et al., 2014; Kirmeyer III, et al. 2012; Fierner et al., 2005; Bouldin et al., 2004; Popp et al., 2003; Wailes et al., 2003). Researching the water quality of on-farm reservoir in Northeast East Arkansas Delta, Moore, Pierce, and Farris (2015), concluded that OFWS have the potential to trap and transform potential contaminants when used in tandem with tail water recovery systems rather than releasing them into nearby water bodies. This result is in accordance with Bouldin et al., (2004). Though studies from other regions have confirmed the benefits of using on-farm reservoirs outweighing the cost in low-level groundwater areas, such conclusions cannot be drawn for every region with relatively low groundwater levels (e.g. East Mississippi) because dissimilarities in weather conditions, soil and other management practices might affect the net return of producers.

The use of irrigation to manage crop production risk in humid areas has been well researched (eg. Dalton, Porter and Winslow, 2004; Williams et al., 1996; Epperson, Hook, and Mustafa, 1993, Vandeveer, Paxton and Lavergne, 1989; Boggess et al 1983; Boggess and Amerling 1983; DeJonge, Kaleita and Thorp, 2007). Most of these studies have identified irrigation as an important tool for reducing production risk. In 1983, Boggess and Amerling used a bio-economic simulation model to simulate the risk and returns of irrigating with a low pressured and medium pressured center pivot irrigation system (CPIS) and found that though irrigation increases crop yield under growing conditions in Florida, a fall in price below a certain threshold could lead to losses. DeJonge, Kaleita and Thorp, (2007) determined the net returns of irrigation production in Iowa. They assumed a CPIS for corn production and found that at a baseline corn price of $2.00/bu, irrigation was unprofitable even though there was an increase in corn yield. But it should be noted that returns and uncertainty of irrigating corn is likely to change due to varying corn prices in recent years (Boyer et al., 2014). For example, corn futures prices have not been below $2.00/bu since 2005 and had not been below $3.00 in Mississippi since 2006 until fall 2016. Williams et al., 1996 compared the net returns of irrigation using CPIS with other irrigation systems. Results from their studies show that it is economically viable to invest in CPIS, but the net returns are very sensitive to crop prices, yield, field size and initial investment cost. Though these studies give an extended understanding on the feasibility of irrigating with a CPIS as a risk management tool, the water storage systems used or assumed in most of the abovementioned studies are wells, unlike the more conservative storage pond considered in this study.

Also most studies used crop-based models to simulate yield data and do not include any other input apart from water (Boyer et al., 2014). Process based crop models are widely used in predicting crop yields, especially when it comes to predicting irrigated yields. Following Urban et al 2012 and Sharma, Rudnick and Irmak, (2013) we chose to use a statistical model to forecast out of sample corn and soybean yields due to the potential uncertainties and substantial requirements needed for calibrating a processed based crop model. One flaw with crop based models is that incorrect assumptions made when calibrating can give misleading results (Graves, 2002). The use of an OLS regression to estimate the relationship between trend, weather variables and crop yield is new in the field of agricultural sciences (Sharma, Rudnick and Irmak, 2013). This technique is gradually gaining acceptance in the field as a recent study by Lobell and Bruke, (2010) and Shlenker and Lobel, (2009) shows that calibrating a statistical model (simple regression equation) with historical yield data and weather serves an alternative to processed based models predicting crop yields.

With limited information about the profitability of OFWS in Mississippi, this study is focused on determining whether corn and soybean producers in East Mississippi are better off investing in an On-Farm Water Storage System for irrigation purposes than depending solely on rainfall. This is specifically achieved by employing a stochastic benefit-cost analysis to analyze net present value (NPV) estimates of both scenarios. Sensitivity analysis is performed on key variables to determine how their variations influence NPV estimates. The analysis takes into account a corn (Zea mays) and soybean (Glycine max) production system in Noxubee county, Mississippi and will include a 17 acre water storage reservoir and a center pivot irrigation system.

METHODS and DATA

Predicting crop yield

Assuming optimal fertilizer application under both irrigation and rain-fed productions, we specified corn and soybean yields as a function of weather and forecasted out of sample irrigated and rain-fed corn and soybean yields for twenty five years. Reports from recent studies (Shlenker and Lobel, 2009; Urban et al., 2012), shows that weather plays an important role in predicting corn and soybean yields. Different specifications were tried to determine the relationship between crop yields and weather. Recent studies have reported the use of degree day models as ideal and superior to other models in terms of forecasting out of sample corn and soybean yields. Though criticized about its inability to capture sub-seasonal variation during growing periods, the use growing season weather averages is still common in statistical approaches. We found that a quadratic specification as shown in equation 1 using seasonal averages to be the best fit for our research.

A quadratic term of temperature and precipitation was specified to reflect the non-linear relationship between yield and weather. Since weather impact on yield is relative rather than absolute, the log of yield was used as the dependent variable instead of actual yield. Using log of yield also helps to reduce heteroscedasticity in response residuals (Urban et al., 2012). Crop yield and weather data for six counties in East Mississippi were used for the regression. We omitted one county in each case and performed four multiple regressions using the specification in equation 1. The regressions were performed on irrigated corn, irrigated soybean, rain-fed corn and rain-fed soybean as follows:

$$(1) \qquad \log(y_{nt}) = \beta + \alpha_1 P_{nt} + \alpha_2 P_{nt}^2 + \alpha_3 T_{nt} + \alpha_4 T_{nt}^2 + \alpha_5 t + c_n + \varepsilon_{nt}.$$

Where $\log(y_{nt})$ is the log yield in county n at time t. P_{nt} and T_{nt} are growing periods monthly precipitation and monthly mean temperature respectively. β is the constant of the regression and $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and α_5 are the coefficient of precipitation, temperature and time variables t. County specific conditions such as soil type, management and production practices that are omitted is captured by the dummy variable c_n. ε_t is the stochastic error term. We included a linear time trend which account for technological changes over growing periods.

The coefficient estimates from the regressions were then used together with randomly drawn weather variables to forecast out of sample yields for twenty five years. In predicting crop yield, we followed Wooldridge, (2009) for predicting from a regression using a log dependent variable. Wooldridge, (2009) explains how exponential predictions from a log dependent variable should be multiplied by an adjustment factor to avoid under predicting. The adjustment factor is the mean of the exponent of the residuals from the regression. Though we estimated the adjustment factor, it did not have much impact on the predicted yields because it was approximately equal to one.

Random variables from the predictions were simulated using Simulation and Econometrics to Analyze Risk (Simetar) under a normal distribution assumption. According to Richardson (2006), random variables can be simulated either by using historical mean and standard deviation for the residual or by using forecasted values beyond the historical data and the standard error of the predictions. With twenty five years of out of sample predictions, the latter was used to simulate random corn and soybean yields as $Norm(\hat{y}_{nt+1}, sep_{t+1})$. Where sep_{t+1} is the standard error of the predicted yields $(\hat{y}_{nt+1})$ for each county. As representative for the study area twenty five periods were randomly selected from the predicted yields from all six counties.

Price simulation

Stochastic corn and soybean prices were simulated from a multivariate empirical (MVE) distribution using simetar. Simulating random variables from an empirical distribution avoids imposing a specific distribution on variables and it also solves correlation and heteroscedasticity problems among variables (Richardson, Klose and Gray, 2000). Given the fact we are assuming a crop rotation between corn and soybean, it was important not to have ignored the relationship between their simulated prices. MVE made it possible to establish a correlation between corn and soybean prices even though they are not normally distributed. According to Richardson (2006), MVE can be used to establish a correlation between non-normally distributed variables in a simulation model. Equation 4, was used to estimate the expected corn and soybean prices.

$$(2) \quad P_{jt} = Mean\ price_j \times \left[1 + Emp\left(s_{dj}, f\left(x\right), cusd_j\right)\right]$$

Where P_{jt} is the simulated price for crop j in year t. $Mean\ price_j$ is the mean of the weekly Mississippi corn or soybean prices spanning from January 2007-August 2016. Emp represents an empirical distribution which is specified as a function of sorted deviates from the historical price means (s_{dj}), cumulative probability of the sorted deviates $(f(x))$ and the correlated uniform standard matrix $(cusd_j)$. The correlated uniform standard matrix is obtained from the correlated matrix between corn and soybean prices. Mean prices were used as an alternative to trend forecasted prices because there was no statistical significance between the historical prices and trend.

Hoteling T^2 and Box's M tests were use in validation to check whether the simulated prices follow the same distributions as the historical prices. Specifically, a two sample Hoteling T^2 test failed to reject the null hypothesis that the mean vectors of the simulated and historical prices are equal. Box's M test fails to reject the null hypothesis that the covariance matrices of historical and simulated prices are equivalent. A detailed explanation on how to simulate non-normal distributed variables using a MVE distribution is in Richardson (2000) and Richardson, Klose and Gray (2000). Barham et al., (2011) used a similar approach to simulate random cotton yields and prices in Texas.

Estimating net returns and cash flows

The stochastic crop yields and prices were incorporated in an economic model to determine the per acre net returns for each crop under irrigation and rain-fed productions over the twenty five years period. Per acre net returns for each crop was specified as $f(p_t, y_{it}(w), \boldsymbol{v_{it}}, \boldsymbol{r_{it}})$. p_t is stochastic crop price in time t, y_{it} is the stochastic yield output modeled as a function of weather (w). $\boldsymbol{v_{it}}$ and $\boldsymbol{r}_{it}$ are vectors of variable and fixed input prices respectively, while i represents either irrigation or rain-fed production. The per acre net returns was then multiplied by the total land area under each production system to obtain the expected annual whole farm net returns before tax (equation 3). Assuming a 50-50 crop rotation between corn and soybean, the whole farm returns for either irrigating or rain-fed was estimated as 50 percent each the returns from corn and soybean. That is, the whole farm returns for irrigating is 50 percent each the total returns from irrigated corn and soybean, and the whole farm return from rain-fed production is 50 percent each the total returns from rain-fed corn and soybean. A_i is the to the total land size under each scenario.

$$(3) \qquad E(\pi_{it}) = 0.5\, E\left[((p_{ct} y_{cit}(w) + z_{\alpha cit}) + (p_{st} y_{sit}(w) + z_{\alpha sit})) - ((\kappa_{ct} + \phi_{ct}) + (\kappa_{st} + \phi_{st}))\right] \cdot A_i$$

Expected whole farm annual returns (π_{it}) is weighted by 0.5 to account for the fact that it is a function of 50 percent each of the revenue and cost of corn and soybean production under either irrigation or rain-fed. p_{ct} is the stochastic corn price in year t, $y_{cit}(w)$ is the stochastic corn yield for either irrigation or rain-fed production and is a function of weather (w). p_{st} and $y_{sit}(w)$ are the stochastic soybean prices and yields respectively. $z_{\alpha cit}$ and $z_{\alpha sit}$ are the per acre indemnity payments received for corn and soybean insurance respectively. α is dummy variable with value 1 under crop insurance and 0 with no insurance. Indemnity payments are received only when the respective actual revenues from a production period falls below that of the guaranteed revenue. The sum of the per acre variable and fixed input costs for corn and soybean production gave annual total specified cost on per acre basis for corn (κ_{cit}) and soybean (κ_{sit}). $\varphi_{\alpha cit}$ and $\varphi_{\alpha sit}$ represents the premiums for crop insurance paid under corn and soybean production respectively. Premium payments was assumed to be constant over the twenty five years period.

Out of the total land area of 408 acres, 17 acres has gone into construction of an OFWS but 339 acres gets irrigated annually due to the structure of the center pivot irrigation system. Hence in estimating the whole farm returns for irrigating, the annual per acre returns of irrigating were multiplied by 339 acres and per acre returns from rain-fed was multiplied by 52 acres. The sum of these two estimates yields the annual whole farm returns before tax for irrigating. 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 goes unirrigated, although crops are still grown on the corners. Whole farm net returns for rain-fed production is the product of per acre annual returns for non-irrigated land and total land size of the research farm (408 acres). Note that the total land size for irrigation production on the research farm is 391 acres. This is because 17 acres has gone into construction of the water storage system.

The total investment cost for installing an OFWS and a center pivot irrigation system was depreciated over a 5-year period, hence the expected taxable returns from the irrigating investment is obtained by subtracting the depreciated amount from the whole farm net returns before tax. Taxable returns was estimated using equation 4.

$$(4) \quad E(\pi'_{it}) = \pi_{it} - dep_5$$

Where π'_{it} the expected taxable net returns is in year t. dep_5 is depreciation over a five year period. π_{it} is the expected whole farm annual returns before tax for either irrigation or rain-fed from equation 3.

Amount paid in taxes is then obtained by multiplying the estimates from equation 4 by a tax rate. In this study a tax rate of 30% was assumed. Expected annual cash flows to be discounted were estimated by subtracting the amount paid in taxes from the total returns before tax. This is shown in equation 5.

$$(5) \quad E(\theta_{it}) = \pi_{it} - \left(\pi'_{it} \cdot \phi\right)$$

Where θ_{it} is the expected annual cash flows, the product of π'_{it} and ϕ gives the amount paid in taxes with ϕ as the tax rate. π'_{it} is the taxable net returns from equation 4, and π_{it} is the expected whole farm annual returns.

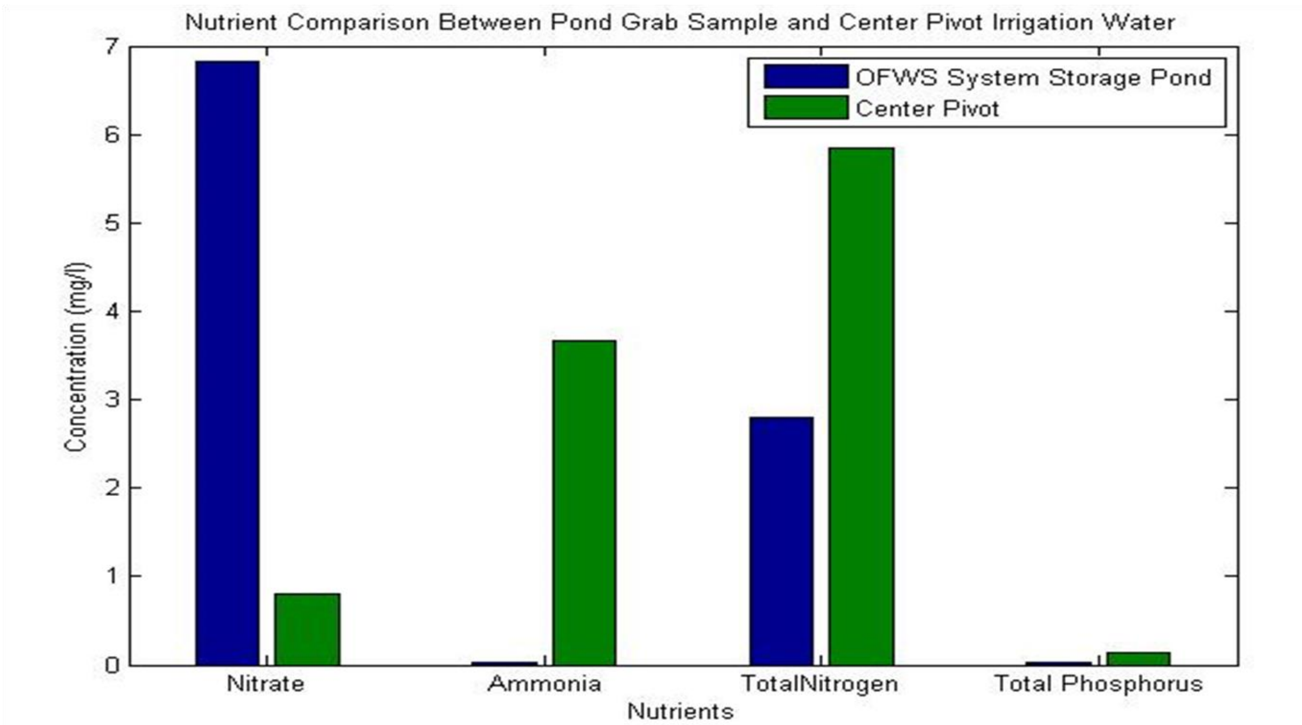
Cost Savings for Nutrient Recycled

In estimating the returns for OFWS, we included the potential dollar savings for nutrient recycled. Not all nutrients applied to agricultural lands are used entirely by plants, some may be lost to downstream through irrigation or rainfall run-off. Research has shown that on the average about 80%, 75%, and 65% of N, P, and K are absorbed by corn at the time of tasseling. Hence some percentage of the applied nutrient will be lost from the field at any point in time if run-off occurs. It is no surprise Doering et al 1999, reported that 95% of total nitrogen that flows in the Gulf of Mexico is from agricultural lands. This finding would not have been possible if all the nutrients applied to the field is absorb by plants. Recent works have shown that OFWS saves significant amount of nutrients from flowing downstream, which means the possibility of recycling the captured nutrients can save producers significant amount of dollars annually on fertilization.

Cost savings enjoyed by crop producers for nutrient recycled back onto the field from the use of OFWS is included in the net present value analysis to determine how it impacts the cash flows. Preliminary findings from Target et al., (2015) on the same research farm considered in this study indicates that, the water storage system captures significant amount nutrients that would have gone downstream but only a few percentage of this captured nutrients is recycled back onto the field. But the recycled nutrients may not be the true representative of the nutrient load because the grab samples are taken from the surface of the pond. Hence, does not reach the settled nutrients at the bottom of the pond. Concentration of nitrate (NO_3), ammonia (NH_3), total kjeldahl nitrogen and dissolved orthophosphate was analyzed within six weeks interval during the 2015 growing season, and 53 tons sediments was reportedly captured during 2014 and 2015 growing season on the same farm.

The Environmental Protection Agency, USA 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 samples over two monitoring periods reported by Target et al., (2015). Total phosphorus recycled is the sum of the phosphorus concentrations from the center pivot irrigation system. Total nitrogen and phosphorus recycled were found to be 8.6mg/L (1.95 lb/acre/inch) and 0.3mg/L (0.07 lb/acre/inch) respectively. By multiplying the respective per acre estimates by the cost of nitrogen and phosphorus applied per acre (reported in Mississippi State University Planning Budget, 2016) we found that for the 339 acres of the research farm that gets irrigated, $519 and $1,288 can be saved annually on phosphorus and nitrogen fertilization respectively. This represents a total cost savings of $1,976 annually. The amount saved on nutrient recycled was accounted for in all years apart from the first year of investment based on the assumption that irrigation from the storage system begins in subsequent years.

Figure 1



Source: Target et al., (2015).

Net present value.

After identifying all benefits and cost of a project in monetary values, it is important to convert them to present value due to 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 (NPV), Internal Rate of Returns (IRR) and the Benefit Cost Ratio (BCR) which is the ratio of the present value benefits to the present value cost of the project. These criteria sometimes give different rankings when choosing among investments (Osborne, 2010). The NPV has been widely used to evaluate the economic worth of water storage and irrigation systems (eg. Falconer, Lewis, Kruz, 2015; Boyer et al., 2014;Williams et al., 1996; Boggess and Amerling 1983; Boggess et al., 1983). We chose to employ the NPV approach to analyze the returns of irrigation above non-irrigating using a CPIS. According to Kay et al., 2008, the net present value approach is the most preferred among 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.

The net present value of the system can be calculated from the equation below, the initial investment cost for the irrigation system inv, η the discount rate and L is the assumed useful life of the investment. $\Delta\theta_t$ represents the change in cash flows between the two scenarios in time.

(5) $$NPV_d = -inv + \sum_{t=1}^{L} \frac{E\left[\Delta\theta_t\right]}{\left(1+\eta\right)^t}$$

Equation 5 explains the fact that this seeks to determine the returns of irrigation above non-irrigation by estimating the difference between the expected cash flows for rain-fed and irrigating production. A positive NPV_d from equation 5, means returns for producers with 50-50 crop rotation between corn and soybean under irrigation production is greater than that rain fed production, meaning it is worthwhile to invest in the system and a negative NPV_d means the project should not be undertaken but depend on rainfall. A zero NPV_d indicate the returns from investing in the irrigation system is not different from relying on rainfall over a twenty five year period. The useful life (L) of the center pivot irrigation system is assumed to be twenty five years with a zero salvage value, similar to assumptions made by (DeJonge, Kaleita and Thorp, 2007; Lamm, O'Brien, and Rogers , 2015) for a center pivot irrigation system. The discount rate

(η) for any given investment varies from person to person, because it is equivalent to the rate of the equity capital used in each enterprise that returns in its most favorable alternative use (Falconer, Lewis and Krutz, 2015). For this reason the discount rate was varied over a range of 1% to 10% in a sensitivity analysis.

Probability Distribution of Difference in Net Present Value

Probability distributions of the differences in the net present values (NPV) between rain-fed and irrigating from an OFWS were represented in cumulative distribution functions (CDFs) to determine the probability at which the net present value estimates for investing in an OFWS over a 25 year period falls above that of depending of rainfall and vice versa. We created 10 different charts each with five CDFs at a specific discounting rate. Each chart compares five CDF's representing NPV_d without crop insurance and NPV_d with crop insurance at four coverage levels.

Cumulative distribution functions are normally used in comparing risky alternatives or management practices. The best or dominant alternative under first-order stochastic dominance is the CDF farthest to the right provided it does not cross other CDFs (Chavas, 2004). For CDFs that intersect, a risk averse decision maker's choice is the CDF with the smallest area under it during the period is dominated. This is considered to be second-order stochastic dominant over a CDF with large area under it during the period is dominated. This allows for once or multiple intersections as explained by Chavas (2004). In this study the probability distributions of NPVs of the two alternatives under consideration is represented by their difference. Hence, as the NPV of investing in an OFWS gets higher than rain-fed the CDF moves to the right and the opposite occurs as the NPV of rain-fed falls above that of investing in an OFWS. In other words CDFs with no or low percentage of the NPV of rain-fed production falling above that of irrigating from an OFWS shows that irrigation investment is worthwhile. For example, CDF_1 which intersects the probability line at 0.3 will be on the right side of CDF_2 which intersect the probability line at 0.8. This example interprets as, there is 70% chance of the NPV of investing in an OFWS been higher than that of depending on rain-fall for CDF_1 as compared to 20% chance for CDF_2.

Data

Daily precipitation, maximum and minimum temperatures for the six East Mississippi counties were obtained from the Parameter-Elevation Relationship on Independent Slopes Model (PRISM) data base. Average of the daily maximum and minimum temperatures were estimated to be the representative of temperatures conditions for each day. We then estimated monthly temperatures as the mean of the daily temperatures within each month over the growing period. We assume a five month growing season, starting in April through August for both corn and soybean. It is well documented that weather conditions during these months have significant influence on crop growth and yield potential. Monthly precipitation was estimated as the cumulative daily precipitation within each month.

Annual average historical rain-fed and irrigated corn and soybean yield data for six East Mississippi counties from the Risk Management Agency was used. Farm-level yield data would have been ideal for this study, but due to unavailability of long term farm-level data, county level data spanning from 1991-2014 was used. From the historical data, corn and soybean yields were modeled as functions of the weather variable and randomly projected for twenty years.

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 Planning Budget (based on 2016 budgets). Following Dalton et al., (2004), we created a stochastic component in the cost of irrigation per acre. Labor cost per acre and cost of hauling are stochastic and dependent on the amount of rainfall received and quantity of crop output respectively. The planning budget provides an expected irrigation labor price of ($1.84/acre/in). With low groundwater condition in the study area, we assumed a maximum application amount of 6/in/acre for both crops. Hence the cost of labor per acre was estimated as the product of 6in/acre and the expected price of 1.84/acre/in if the difference between the 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. We fix required precipitation for corn and soybean growth at twenty five inches per season. The cost of constructing and maintaining the OFWS from the research farm was provided by Mary-Love Target and Jao Paz (through personal communication).

Coverage levels of 70%, 75%, 80% and 85% were used in calculating the premiums paid for crop insurance. Premiums paid for crop insurance under irrigation and rain-fed productions were obtained from an online United Stated Department of Agriculture (USDA) cost calculator for the study area (Risk Management Agency-USDA, 2006). This tool has been used recently to estimate crop insurance premiums (e.g. Boyer et. al., 2015; Barham et al., 2011; Dalton et al., 2004). A ten year (2005-2014) average of corn and soybean yields for Noxubee county used as a production history. Noxubee county was selected in calculating the premiums because of the location of the OFWS under consideration (Brooksville site in Noxubee). The cost estimator projected 2016 corn and soybean prices as $3.89 and $8.86 respectively. Mississippi weekly corn and soybean prices spanning from January, 2007 to August, 2016 was obtained from the USDA data base.

Preliminary Results

Yield response

Rain-fed corn, rain-fed soybean, irrigated corn and irrigated soybean had a respective coefficient of determination values of 0.52, 0.47, 0.7 and 0.62. With the influence of significant factors such as fertilizer applied not accounted for, these values shows how precipitation, temperature and changes of over time influences crop yields. Monthly precipitation was significant at 1% and 5% levels on rain-fed yields and irrigated corn respectively. But precipitation was not significant on irrigated soybean. This is an indication that soybean receives required amount of irrigation water in the study area as compared to corn. The parameter estimates for monthly temperature were positive for all four regressions but not significant on the irrigated yields. Jointly, the explanatory variables in all regressions explains a significant portion of crop yield and this is shown in a significant F-statistics at 1% significant level. Summary of the simulated out of sample yields are reported in Table 4.

Net Present Value Results

Using the sizes of land area under production and an OFWS on a research farm in Noxubee county as a base, preliminary results indicates that, investing in an OFWS as an alternative to depending on rainfall production in low ground level could increase producers returns significantly. However, producers may be better off depending on rainfall than to make such an investment when interest rates are high. Starting from a one percent discounting rate (Table 1), it can be concluded that, without revenue protection the expected net present value of irrigating from an OFWS is higher than that of rain-fed until interest rate reaches a high of 8% and this can be seen from an average positive net present value difference (NPV_d) of $372,755, $277,608, $210,608, $152,287, $112,255, $54,275, $11,183 at interest rates from 1% to 7%

respectively. This means that at this interest rates, it is worthwhile for crop producers practicing 50-50 crop rotation between corn and soybean under East Mississippi conditions to invest in an OFWS or producers will be better off making such an investment rather depending of rain-fed production because not only is the net present value of the cash flows of the of the irrigation investment positive but is also higher than that of rain-fed. On the average, net present value of rain-fed production is $26,770, $58,524 and $80,705 higher than investing in an OFWS at interest rates of 8%, 9% and 10% respectively.

Including crop insurance makes irrigation more attractive, which is evident in higher NPV_d's. For example without crop insurance, producers may be better off practicing rain-fed production at 8% interest rate (shown in a mean NPV_d of $-26,770) but protecting the revenues generated under both irrigation and rain-fed production at 70% coverage level raises the net present value estimate of irrigation above that of rain-fed. This is can be seen in a positive NPV_d of $15,726 and it keeps increasing as the coverage level increases, it increases up to $32,239 at 85% coverage level. As mentioned, increase in coverage levels increases the average NPV_d, however, findings shows that it is worthwhile to dependent on rainfall than making the irrigation investment with or without crop insurance (at coverage levels from 70% to 85%) at interest rates of 9% and 10%.

Crop insurance significantly reduces the variability in both production under irrigation and rain-fed production, this is evident in the reduction in standard deviation at each discounting rate. The probability distributions of the NPV_d over the twenty five years period (represent in CDF's) shows that without crop insurance there is about 88%, 81%,80%, 77%,70%,60%, and 56% chance of the irrigation investment been profitable than depending on rainfall at 1% to 7%

discounting rates respectively. The probability of irrigation been profitable as compared rain-fed production decreases below 50% when interest rates are above 7%, with a low of 37% chance of profitability at a 10% interest rate. The use of OFWS with a center pivot irrigation system proves to be worth it at low interest rates as compared to rain-fed production when revenues generated are protected under crop insurance (at coverage levels of 70% to 85%). This is because the probability distribution of the NPV_d shows that there is zero percent chance of the net present value of irrigating falling below that rain-fed production at 1% to 4% discounting rates. However, there is about 75% probability of rain-fed production generating higher net present value compared to irrigation when interest rates are 10% and above for all four coverage levels. Charts for 1% and 10% discounting rates are reported in Figure 2a and 2b respectively.

Just as the discounting rates, sensitivity analysis shows that net present value estimates are very sensitive to variation in initial investment cost. This is in accordance to Williams et al., (1996). Table 2 reports the simulated averages of the NPV_d at ±5% and ±10%. Generally, a decrease in initial investment cost significantly increases the net present value of irrigating above that of rain-fed production. Though 5% and 10% increase in initial investment cost reduces the profitability of irrigating, on the average investing in an OFWS yields higher net present value compared to rain-fed production until interest rate reaches 7%. The average NPV_d of $-26,770 without crop insurance increases to $-74,311 and $18,563 upon 5% and 10% decreases in initial investment cost respectively. These estimates indicates that producers may be better off depending on rainfall for production even with a 5% reduction in the initial investment cost but irrigation investment becomes more profitable when there is a 10% decrease in the cost of the irrigation system at 8% interest rate. A 10% increase in the initial investment cost at the same interest rate make rain-fed production more profitable by generating an average NPV_d of $-61,369. A 10% decrease in initial investment cost significantly increases the net present value of irrigation over the twenty five years period, but this reduction is not enough to make irrigation more profitable than rain-fed production when interest rates are 9% and 10%. A positive NPV_d of $1,065 was found at 85% coverage level, when initial investment cost increases by 10%.

Summary and Conclusion

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 OFWS and irrigating with a CPIS in East Mississippi. Net present value estimates are compared to an alternative of 'do nothing' or rain-fed corn and soybean production to determine which scenario will yield higher returns for producers. 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 gives a good insight to producers and investors as to whether it is worthwhile to invest in the system or producers would be better off depending on rainfall. The study takes into consideration the size of a research farm in Noxubee county which has a 17 acre size of an OFWS. A statistical models was used to forecast corn and soybean out of sample yields based on the assumed useful life of the irrigation system. The riskiness of the investment is accounted for my incorporating stochastic prices and yields.

Preliminary findings suggests that, if corn and soybean producers can afford investing in an OFWS at low interest rates, then they will receive higher returns for irrigating compared to rain-fed production. As expected increase in interest rates reduces the net present value of making such as investment significantly and this is more evident when interest are above 7%. The use of OFWS becomes more attractive when revenue generated are protected under crop insurance. As the coverage level increases the net present value of investing in an OFWS increases well above that rain-fed production, however there's over 60% chance of rain-fed production been more profitable than irrigating at all coverage levels considered when interest rates are over 9%. The profitability of investing in an OFWS can significantly be increased or the percentage of the net present value of rain-fed production fallen above that of irrigating can be reduced drastically if a more efficient irrigation system which can irrigate the whole land area under production is used. Reduced nutrients loss through runoff and potential government incentives for the systems environmental impacts can make the use of OFWS very profitable than rain-fed production. But as with many commodities in the market, as demand for such irrigation investment increases, the initial investment cost is also likely to increase, however preliminary finding shows that, even with a 10% increase in initial investment cost, interest rate must be over 7% before the returns from rain-fed production becomes higher than that of making the investment.

With no government incentives for most crop producers in East Mississippi, the percentage of net present value of irrigating from an OFWS been higher than rain-fed can be increased should crop producers receive some incentives for investing in OFWS. I should also mention the system's role in protecting water quality of nearby water bodies was not accounted for in this study. A couple of studies (Popp et al, 2003, Wailes et al, 2003, Target et al, 2012) have reported that OFWS saves significant amount pollutants from agricultural land from flowing downstream but this impact was unquantified in this study.

Providing crop producers in the study area with government incentives to prevent sediment loss and inflow of pollutants from agricultural land through the use OFWS will increase its profitability significantly and make it more desirable as compared to rain-fed production. Work is still in progress to determine the profitability of investing in an OFWS using different sizes of land and storage reservoirs in East Mississippi.

Table 1. Simulated NPV difference between rain-fed and irrigation at various crop insurance coverage levels and discount rates

		0.01	0.02	0.03	0.04	0.05
	Mean($)	372,755	277,608	210,392	152,287	112,255
No Insurance	SD($)	327,385	290,793	264,936	240,203	230,168
	Min($)	(885,078)	(596,677)	(697,186)	(705,354)	(738,316)
	Max($)	1,646,732	1,278,513	1,007,788	988,563	829,677
	Mean($)	413,102	327,916	254,056	193,110	142,709
	SD($)	117,618	106,274	95,177	88,184	81,131
70% CL	Min($)	111,096	68,552	16,526	(7,044)	(67,253)
	Max($)	881,935	727,942	670,248	660,458	498,735
	Mean($)	422,196	338,203	265,501	197,549	140,708
	SD($)	111,794	99,874	91,255	79,289	71,393
75% CL	Min($)	149,109	69,531	76,394	7,540	(53,993)
	Max($)	877,238	731,652	610,947	529,311	393,360
	Mean($)	435,769	346,724	269,921	204,790	150,690
	SD($)	104,223	89,637	81,936	71,839	66,557
80% CL	Min($)	183,801	102,145	53,338	33,467	(14,725)
	Max($)	783,039	808,951	594,816	513,634	436,127
	Mean($)	450,874	359,995	282,768	216,154	161,722
	SD($)	97,811	83,070	72,109	67,850	63,576
85% CL	Min($)	211,832	189,987	111,571	61,760	6,392
	Max($)	853,121	774,262	282,768	519,310	473,920

Table 1 cont'd. Simulated NPV difference between rain-fed and irrigation at various crop insurance coverage levels and discount rates

		0.06	0.07	0.08	0.09	0.1
No Insurance	Mean($)	54,275	11,183	(26,770)	(58,524)	(80,705)
	SD($)	205,017	192,389	185,585	170,993	164,496
	Min($)	(534,903)	(582,689)	(670,965)	(804,202)	(688,497)
	Max($)	738,472	592,086	500,418	494,021	433,832
70% CL	Mean($)	88,074	51,732	15,726	(13,531)	(44,517)
	SD($)	72,197	70,139	65,474	61,660	60,175
	Min($)	(90,013)	(111,758)	(164,110)	(171,100)	(160,725)
	Max($)	364,451	378,002	271,948	285,899	249,923
75% CL	Mean($)	97,030	56,956	18,783	(10,755)	(40,139)
	SD($)	70,551	66,088	58,243	58,214	54,172
	Min($)	(74,820)	(96,456)	(109,263)	(157,101)	(156,800)
	Max($)	433,657	392,774	233,192	306,002	211,535
80% CL	Mean($)	107,868	61,436	23,756	(8,585)	(36,388)
	SD($)	66,097	57,336	56,123	51,019	48,111
	Min($)	(29,558)	(101,107)	(102,179)	(122,349)	(133,912)
	Max($)	489,234	298,086	288,085	205,772	167,077
85% CL	Mean($)	112,276	70,208	32,239	985	(27,488)
	SD($)	55,975	55,928	52,963	50,329	46,234
	Min($)	(21,589)	(61,088)	(76,181)	(110,555)	(117,976)
	Max($)	357,669	324,572	318,884	275,209	189,065

Figure 2a

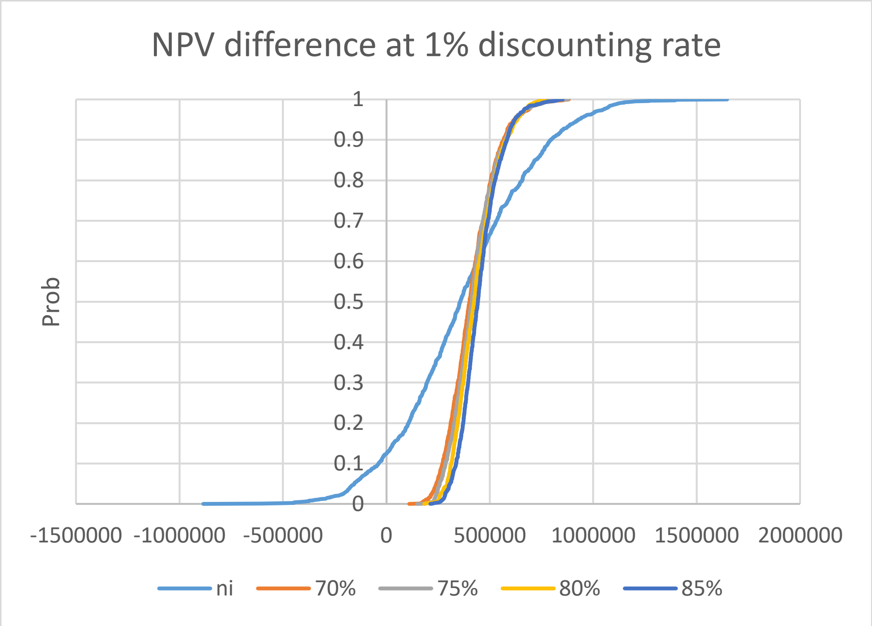
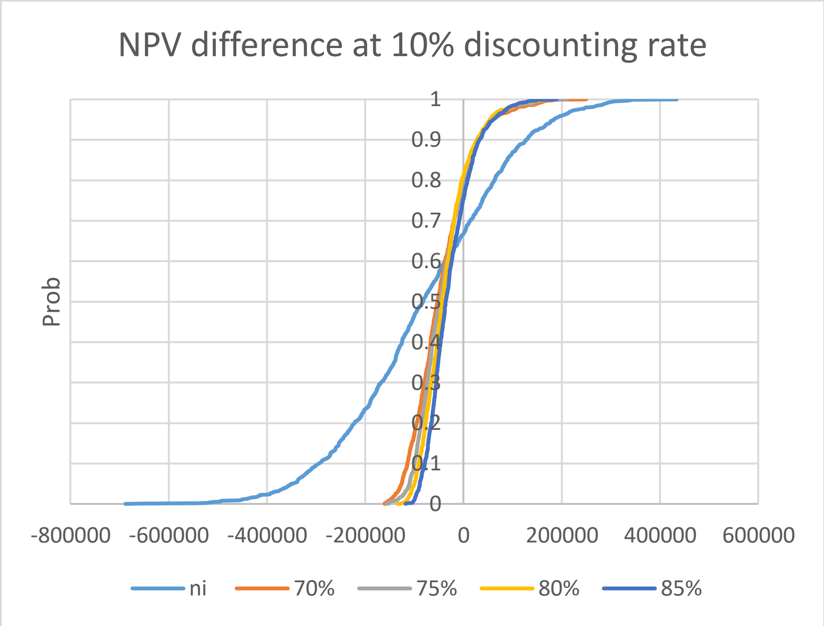


Figure 2b



NB: ni is ‘No insurance’ and 70%, 75%, 80% and 85% are coverage levels.
The x-axis are NPV differences in dollars.

Figure 2a and 2b shows the net present value difference at 1% and 10% discounting rates respectively. Without crop insurance, there is 12% chance of rain-fed production generating higher NPV than irrigating at 1% discounting rate and it increases to 68% chance when discounting rate is 10%. The NPV of irrigation is always higher than depending on rainfall at 1% discounting rate for all four coverage levels.

Table 2. Simulated NPV differences (averages) between rain-fed production and irrigation at various crop insurance coverage levels and discount rates. Reported values reflects ±5% and ±10% variations in initial irrigation investment cost.

	%		0.01	0.02	0.03	0.04	0.05
No Insurance	5	$	382,507	302,029	240,852	173,530	119,276
	5	$	354,627	279,131	197,424	142,715	79,768
	10	$	411,136	340,594	247,780	190,237	130,429
	10	$	333,382	240,575	167,497	95,163	57,622
70% CL	5	$	431,069	343,564	270,906	210,159	155,845
	5	$	401,085	309,638	239,013	177,850	119,427
	10	$	441,855	358,568	287,501	228,289	177,953
	10	$	376,329	299,183	225,177	161,473	104,273
75% CL	5	$	448,250	352,985	277,221	214,617	161,655
	5	$	408,221	319,597	244,264	183,368	127,199
	10	$	456,252	367,234	295,020	229,893	178,577
	10	$	396,568	307,725	229,903	163,030	111,120
80% CL	5	$	453,439	367,918	289,763	220,688	169,594
	5	$	426,249	335,129	254,461	189,007	133,786
	10	$	470,106	376,629	305,709	241,370	183,888
	10	$	403,071	315,158	237,156	173,382	116,914
85% CL	5	$	471,104	373,890	299,906	233,819	177,182
	5	$	438,855	347,072	268,632	202,112	141,982
	10	$	486,647	393,368	318,525	251,925	195,946
	10	$	419,788	326,783	251,473	186,568	125,499

NB: Bold percentages represents increase in initial investment cost.

Table 2. cont'd. Simulated NPV differences (averages) between rain-fed production and irrigation at various crop insurance coveragelevels and discount rates. Reported values reflects ±5% and ±10% variations in initial irrigation investment cost.

	%		0.06	0.07	0.08	0.09	0.1
	5	$	74,910	34,149	(7,431)	(25,395)	(57,407)
	5	$	41,822	(5,002)	(44,446)	(68,625)	(91,907)
No Insurance	10	$	87,450	45,746	18,563	(10,900)	(38,103)
	10	$	16,703	(19,883)	(61,369)	(99,397)	(125,566)
	5	$	106,258	67,172	34,172	2,630	(24,737)
	5	$	67,912	32,360	247	(33,586)	(59,796)
70% CL	10	$	124,434	85,389	50,842	19,483	(9,544)
	10	$	55,725	15,623	(18,681)	(48,247)	(80,255)
	5	$	114,138	72,175	35,062	4,275	(23,228)
	5	$	77,582	38,346	3,345	(28,636)	(57,538)
75% CL	10	$	125,997	88,742	51,221	24,957	(5,337)
	10	$	62,673	22,254	(15,280)	(46,015)	(75,272)
	5	$	121,455	80,087	45,741	9,236	(17,299)
	5	$	87,837	44,629	10,507	(23,324)	(50,978)
80% CL	10	$	135,229	92,402	59,200	26,699	3,049
	10	$	68,837	27,089	(6,052)	(42,660	(65,661)
	5	$	128,553	86,601	49,706	18,410	(12,182)
	5	$	94,843	55,620	15,801	(16,377)	(47,912)
85% CL	10	$	144,654	103,539	67,006	36,006	7,559
	10	$	77,411	36,367	1,065	(32,554)	(62,775)

NB: Bold percentages represents increase in initial investment cost.

Table 3. Parameter estimates for yield responds function

	Non-irrigated corn	Non-irrigated soybean	Irrigated corn	Irrigated soybean
Intercept	-16.8	-23.1	-15.10	-7.20
Temp	0.82*	0.94*	0.72	0.38
Temp2	-0.01*	-0.01*	-0.01	-0.003
Prec	0.05***	0.098***	0.04**	0.01
Prec2	0.001***	-0.002***	-0.001**	-0.0001
Time	0.02***	0.02***	0.03***	0.02***
R-square	0.52	0.47	0.70	0.60

***, ** and * indicates significance at 1%, 5% and 10% respectively.

Table 4. Simulated corn and soybean yield under irrigation and rain-fed production

	Rain-fed soybean	Irrigated soybean	Rain-fed corn	Irrigated Corn
Mean (bu/acre)	37	53	130	174
SD (bu/acre)	3	4	9	20
Min (bu/acre)	26	41	96	103
Max (bu/acre)	47	70	166	244

Table 5 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
Total Direct Expenses				
Fixed Expenses				
Implements	acre	9.14	1	9.14
Tractors	acre	11.45	1	11.45
Harvesters	acre	1356	1	13.56

Source: MSU Extension planning budget for Non-Delta area.

Table 6 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				155.10
Operator Labor				
Tractors	Hour	13.4	0.4823	6.34
Harvesters	Hour	13.4	0.01277	0.17
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	3.6449	6.20
Harvesters	Gal	1.7	1.7419	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 areas.

Table 7. Cost of Irrigations System

	Cost
On Farm Storage Reservoir	$145,000
Tailwater recovery ditch	$0
Center Pivot irrigation system	$302,000
Total cost	$447,000

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