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Economic Feasibility of Irrigation Along the McClusky Canal in North Dakota: Farm-level Returns

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Executive Summary

The Dakota Water Resources Act passed in 2000 by the 106th Congress mandates the maintenance of the McClusky Canal and authorizes the development of 51,700 acres for irrigation along the canal. The purpose of this study is to 1) estimate farm-level returns to irrigation to gauge farmer willingness to invest in irrigation and produce irrigated crops and 2) provide inputs for a complementary study that estimates state-level economic effects of expanded irrigation.

Farm-level returns are estimated using traditional enterprise budgets as well as stochastic budgets which account for variability in crop yields. The stochastic budgets require knowledge of the distribution of crop yields which are estimated using historical crop yields from the North Dakota State University Research Extension Centers at Carrington and Minot. An irrigated rotation of primarily corn and a dryland rotation of spring wheat-canola-spring wheat-soybeans were selected as representative rotations for comparison.

The annual benefit of irrigation to the farm operator, based on average dryland yields (spring wheat, canola and soybeans) and irrigated yields (corn), is $56.71 per acre. This added return increases the value of irrigable land by $1,418 (56.71/.04). A stochastic analysis of dryland and irrigated yields projects an increase of $1,700 per irrigable acre over the next decade.

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Introduction

Economic evaluations of the profitability and economic impacts of irrigation development in North Dakota have been periodically conducted since the 1950s. The most recent studies to examine farm-level economics and economic impacts were conducted in the 1990s (Givers et al. 1994; Leitch et al. 1991). While the general economic methods used remain relevant, changes in prices, crop rotations and yields, production practices, government programs, and the natural climate have almost certainly altered the results. In addition, developments in the measurement of risk on investment decisions can now be used to better understand potential returns to individual producers and the public.

North Dakota again faces a potential opportunity to expand irrigation in central North Dakota. This report is part of a larger research project exploring the economics of expanded irrigation in central North Dakota from the perspective of agricultural producers and the state.

Background

Congress authorized the construction of Garrison Dam on the Missouri River in North Dakota in the 1940s and construction began in the 1950s. The intended benefits of the Garrison Dam included irrigating agricultural land in central North Dakota. Based on the technology at that time, the water would be moved via canals and applied by flood-type irrigation. Some of the primary features of the overall project would be the Snake Creek Pumping Plant to lift water from Lake Sakakawea to maintain the water level in Lake Audubon. The McClusky Canal would then convey water from the eastern edge of Lake Audubon into central North Dakota.

Construction of the pumping plant and several canals commenced in the 1960s, but the overall project was not completed due to a variety of concerns, including the environmental impact of moving Missouri River water into the watershed of the Red River of the North. Accordingly, the McClusky Canal -- although constructed -- is blocked near the continental divide between the Missouri River and Red River basins. This point is located several miles north of the community of McClusky, North Dakota, in Sheridan County. The length of the McClusky Canal from its source at Lake Audubon to its point of blockage is approximately 60 miles, within McLean and Sheridan counties.

Despite the inability to complete the original Garrison Diversion project, there is continued interest in pursuing projects to supply water from the Missouri River to meet a variety of needs in central and eastern North Dakota. One such project is the "MileMarker 7.5" irrigation project along the McClusky Canal. The features of this irrigation project include a

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pump site on the McClusky Canal 7.5 miles from its origin on Lake Audubon, hence, the name of the project. Five electric-powered pumps move water through buried pipelines to irrigate approximately 4,000 acres (i.e., 30 center-pivot irrigation systems) along the north side of the McClusky Canal. This development is part of The Dakota Water Resources Act passed in 2000 by the 106th Congress which authorized developing 51,700 acres of irrigation in central North Dakota.

The question of the economic viability of irrigated crop production is unanswered. Although a series of economic analyses of diverting water from the Missouri River into central and eastern North Dakota have been completed since the 1960s, an updated analysis is needed again. Changes in the technology of conveying and applying irrigation water (i.e., buried pipes and center pivot sprinkler irrigation systems), crops being produced, and crop production technologies are only a few of the reasons for needing an updated analysis. The commitment by the State of North Dakota to expand irrigation by funding a share of the cost of constructing the irrigation infrastructure in central North Dakota also impacts the economics of this effort.

Problem Statement

Changes in market prices, technology, climate, government policy, and production practices have altered the economics of crop production. Increased demand for agricultural products and limited ability to supply them have placed upward pressure on prices, incentivizing increased production. At the same time, high levels of price volatility and production risk have led many farmers to be conservative when considering new practices or investments as well as seeking ways that reduce these risks. Irrigated production may provide for increased production while decreasing variability due to limited water availability.

Numerous changes have occurred since the last detailed study of irrigated crop production in North Dakota. Consequently, there is limited, recent research to strongly support or discourage farmers from developing on-farm irrigation and for public investment in supporting infrastructure.

Purpose

The purpose of the study is to estimate the returns of irrigated crop production along the McClusky Canal with a consideration of the impact of production risk. A second study (Bangsund, Saxowsky, and Ripplinger 2014) considers the regional economic impacts of irrigation development. The purpose will be achieved by answering the following research questions:

1. What dryland crops are grown in the region?
2. What dryland crop rotations prevail?
3. What are the returns to dryland crop production and crop rotations?
4. What irrigated rotations are possible?
5. What are the returns to the most likely irrigated cropping system(s)?
6. How much do regional dryland and irrigated crop yields vary?

7. What are the expected returns to representative dryland and irrigated crops when yield variability is considered?

This report presents the findings and implications of study on the farm-level returns to irrigated production along the McClusky Canal. The report is organized with a review of previous North Dakota irrigation studies, analytical methods and data, results, and conclusions. Detailed technical descriptions of the methods used and detailed results are presented in the appendices. This report is complemented by Bangsund, Saxowsky, and Ripplinger (2014) that focuses on the regional economic impacts of irrigation development and irrigated crop production.

Previous Irrigation Studies

A number of previous studies, addressing a wide range of issues, have estimated the economic impacts of expanding irrigation in North Dakota. Previous studies conducted over several decades addressed a range of topics. Two studies identified market opportunities for irrigated crops and related agricultural commodities (Podany, 1951; Podany, 1952). Several projects described dryland farming practices in regions of North Dakota where irrigation was expected to be developed (Shaffner, 1951; Schaffner, 1954; Schaffner, 1955; Schaffner, 1958). Researchers analyzed the impact on North Dakota's economy resulting from inundating land along the Missouri river (Johnson & Goodman, 1962; Leitch & Anderson, 1978). Financing for producers adopting irrigation also has been analyzed (Taylor et al., 1972(a); Taylor et al., 1972(b)). More recent studies focused on select agricultural commodities such as livestock, potatoes, malting barley and sugar beets (Johnson et al., 1987; Watt et al., 1988; Bangsund & Leistritz, 1993; Berwick et al., 2001; Coon & Leistritz, 2001; Wilson et al., 2006; Maung & Gustafson, 2010).

Several studies are similar to this effort, that is, an initial step was to determine the profitability of adopting irrigation, followed with an assessment of the regional economic impact of expanded irrigation. Carkner and Schaffner (1975) first identify changes in crop rotations and then estimate economic impacts by sector. They use a composite acre framework, where a weighted average is used to determine revenues, costs, and returns for a single acre. Hvinden et al (1979) estimate increases in net agricultural income for a proposed 32,000-acre irrigation development in southwest Burleigh County (Apple Creek Unit). Their analysis relies on a survey of agricultural producers in the study area and a 100-year period.

Leitch and Schaffner (1984) used differences in dryland and irrigated income flows to conduct an input-output analysis. They found that development of an authorized 250,000 acre irrigation project would increase gross business volume by $153 million and personal income by $50 million annually. Baltezore et al. (1991) determined that the impact of switching irrigated land to dryland would be a reduction of $197 per acre in net income and 130 fewer jobs in the target community.

A comparison of irrigated and dryland production in McKenzie County, North Dakota found returns increased $24 per acre for irrigated crop land without potatoes and $165 per acre increase for a crop mix with potatoes (Givers et al., 1994). Leitch et al. reevaluated the impact of

Garrison Diversion irrigation in 1991 (Leitch et al., 1991). The research recognized that some crops were oversupplied at that time so the analysis distinguished between raising surplus crops and non-surplus crops in three regions of the state. The study concluded that irrigation would generate a positive on-farm return per acre for all scenarios considered and increase regional employment. Appendix B in the report is of particular interest because it focused on the Turtle Lake region, that is, the same area being studied in the current (2014) research.

Despite these past studies, there are several reasons to conduct an updated analysis. First, the dryland and irrigated crop mix is different in 2014 than in the past. For example, Carkner and Schaffner (1975) compare a dryland crop mix consisting of wheat (41%), fallow (29%), alfalfa (17%), corn silage (3%) to an irrigated mix consisting of alfalfa (70%), corn silage (12%), corn grain (18%). A 1994 study (Givers et al., 1994) used two irrigated mixes: 1) corn (23%), wheat (23%), dry beans (21%), alfalfa (12.5%), safflower (12.5%), and sunflower (8%) and 2) potatoes (41%), alfalfa (23%), corn (18%) and wheat (18%). Second, the current study incorporates risk, in the form of yield variation. Carkner and Schaffner (1975) and Leitch et al (1991) point out the value of irrigation in stabilizing production and its consideration when making an investment decision. Third, the current study has a different objective and uses a different base scenario (that is, the fundamental components of the irrigation system – the Garrison Dam, the Snake Creek Pumping Station and the McClusky Canal – are already in place).

These previous studies addressed the issues of farm-level returns to expanded irrigation as well as regional economic impacts. Knowledge of these studies helps inform decision makers. However, changes in technology, policy, and climate have changed returns to dryland and irrigated production.

Analytical Methods and Data

The purpose of this study is to estimate and analyze returns to dryland and irrigated crop production along the McClusky Canal in central North Dakota. In this chapter, the methods and data used are presented. The use of composite acres, selection of crop rotations, the calculation of returns to labor and management, and the use of simulation to estimate variation in returns are described.

Methods

Traditionally, farm-level economics are evaluated on the basis of anticipated revenues, costs, and returns of crop enterprises using crop budgets. This process occasionally includes identification of representative crop rotations, and weighting the revenues, costs, and returns of individual crops to create a composite-acre budget. Composite-acre budgets allow a direct comparison between alternative cropping systems. In past studies, composite-acre budgets have been based on expected yields, prices, and costs (Baltezore et al. 1991; Givers et al. 1994). Expected yields were based on an annual average value, either calculated from production statistics or based on budget-generators assuming certain factors for yield goals.

New analytical tools can now produce budgets that include stochastic elements (i.e., an analysis using probability), to generate a range of results, such as a distribution of net returns for both dryland and irrigated production systems. For example, by examining historical yield data and applying stochastic budgeting approaches, economic evaluations of producer net returns can address variation (hence, risk) In such an analysis, net returns could be expressed in terms of likelihoods of occurrence over given time periods (e.g., project the best annual net return out of 10 years). In addition, the use of stochastic modeling can provide a better long-range assessment of the variability of returns than could be obtained using simple averages or expected yields from budget programs.

This study uses both traditional budgeting and stochastic modeling to produce enterprise budgets for the target region.

As part of the process to address farm-level economics of expanding irrigation, the annual economic costs of irrigation equipment are calculated using purchase cost and expected useful life (see Appendix III). Also, operating costs of applying water and maintaining irrigation equipment are estimated. Finally, the irrigation budgets are adjusted for costs that are influenced by increased yields (e.g., grain hauling) and greater yield potential (e.g., fertilizer). Both dryland and irrigated production expenses were initially derived from the North Central North Dakota Projected 2014 Crop Budgets (Swenson and Haugen 2014; Appendix I).

Crop Rotations

Crop rotations are identified to be representative of crop production in a region, not necessarily the rotations of a specific farmer. Dryland crop rotations can be identified by considering agronomic issues, such as disease and productivity, and economic returns for existing and potential future crops. Irrigated crop rotations are similarly compiled.

Direct Costs, Indirect Costs, and Returns to Labor and Management

Direct costs are the expenses that can be directly associated with a specific enterprise, for example, the cost of seed, herbicide, and drying for the production of corn. Indirect costs are those that cannot be assigned to a specific enterprise, for example, machinery overhead and interest. See Appendices I and II for direct and indirect costs by line item as well as estimated net returns for several crops. Several crops are considered for both dryland and irrigated production: barley, corn, hard red spring wheat, dry beans, and soybeans. For each of these selected crops, the return to labor and management for irrigation exceeds the return for dryland production.

In recognition of crop rotations, farm-level dryland and irrigated crop production returns are estimated using composite-acre budgets. Returns are calculated using 1) the traditional model approach that applies expected revenues, costs, and returns and 2) an alternative method where crop yields are stochastic. Simulation can then be used to estimate the returns for varying crop yields which are based on historical data.

Crop budgets are calculated to estimate economic returns. Consequently, they consider the opportunity cost of inputs, for example, the land rental rate or an interest expense for irrigation investment. Economic budgets can understate returns or profits if opportunity cost exceeds the farm operator's financial costs, but an economic budget accounts for all costs regardless of the operator's use of debt or equity capital, for example. Accordingly, this research uses an economic budget even though it may understate returns for a farm operator with limited debt. Economic budgets can be converted to financial budgets by replacing economic values with accounting values, for example, replacing machinery investment with per acre interest and rental expense of machinery, but that is not done in this analysis.

Data

The analysis relies on expected input and crop prices, and crop yields. The USDA Farm Service Agency (2013) acres planted by crop data are used to identify representative crop rotations.

The 2014 crop budgets from North Dakota State University are used when possible as they provide both the data and structure for much of the required analysis. Use of these numbers provides farmers and other decision-makers consistent values to consider. Two resources are relied on: the projected 2014 crop budgets for north central North Dakota ("North Central Crop Budget", Swenson and Haugen 2013) and the projected budgets for irrigated crops for central North Dakota ("Irrigated Crop Budget", Aakre 2014). Because the methods used to construct the budgets differ, prices from the North Central Crop Budget are used in the Irrigated Crop Budget to assure consistency throughout this analysis. Some values, such as fertilizer costs are rescaled based on targeted yields.

Trial yields for dryland hard red spring wheat (HRS), canola, and soybean from the North Central (Minot) Research Extension Center (NCREC) and irrigated corn, dry bean and spring wheat from the Carrington Research Extension Center (CREC) were used to model variations in dryland and irrigated yields and returns. Data from the NCREC are used as it has a more arid climate than Carrington and may be more representative of the area along the McClusky Canal. Carrington irrigated corn, dry bean, and wheat data are used because no irrigated trials were conducted at Minot. Yield trial data used in the analysis are presented in Table 1.

Variation in yields across years and crop is evident. The variation may be due to a number of causes including excess moisture, drought, inadequate heat, hail, freeze, and disease. All crops except canola show wide variation in production. Dryland spring wheat yields ranged from 23.4 bushels per acre in 2011 to 82.7 bushels per acre in 2009, and irrigated corn yields ranged from 44.9 bushels per acre in 2004 to 205.6 bushels per acre in 2012. This variation is captured when fitting statistical models. Yields of irrigated crops also varied due to production factors other than availability of moisture.

Table 1. Yield Trial Data

	Dryland			Irrigated		
	Spring Wheat (bushels)	Canola* (pounds)	Soybean* (bushels)	Corn (bushels)	Dry Bean (pounds)	Spring Wheat (bushels)
Location	Minot REC	Minot REC	Minot REC	Carrington REC	Carrington REC	Carrington REC
2003	65.9	2,735	30.4	139.1	1,698	78.5
2004	78.0	1,918	47.6	44.9	1,719	87.6
2005	68.0	2,269	41.0	135.3	2,649	63.4
2006	72.7	2,611	56.9	166.9	2,881	87.6
2007	29.3		47.7	148	2,982	61.6
2008	63.6	3,583	17.8	122.1	2,504	86.5
2009	82.7	3,921	22.1	134	2,568	91.3
2010	62.0	3,123	35.2	172.1	2,179	83.8
2011	23.4		30.4	136.8	1,442	
2012	46.9		47.8	205.6	3,380	62.4
2013	54.5	2,502	49.5	174.3	3,326	73.5

Source: North Dakota State University
* Roundup-Ready varieties.

Results

The study estimates the returns to dryland and irrigated crop production. In this chapter, the results of the farm-level analysis are presented. Representative crop rotations are presented, then returns calculated using traditional methods for dryland and irrigated rotations are reported. Results of the time series analysis are summarized next, and the returns when crop yield is modeled stochastically are presented last.

Representative Crop Rotations

Identification of representative dryland and irrigated crop rotations was conducted to provide the basis for economic comparison. A number of rotations were evaluated on the basis of agronomics, expected profitability, as well as recent and expected production. Acres planted by crop for McLean and Sheridan Counties are presented in Figure 1. While wheat continues to dominate planted acres, many crops are planted each year in central North Dakota. Corn and soybeans have seen significant increases in acreage in the past decade.

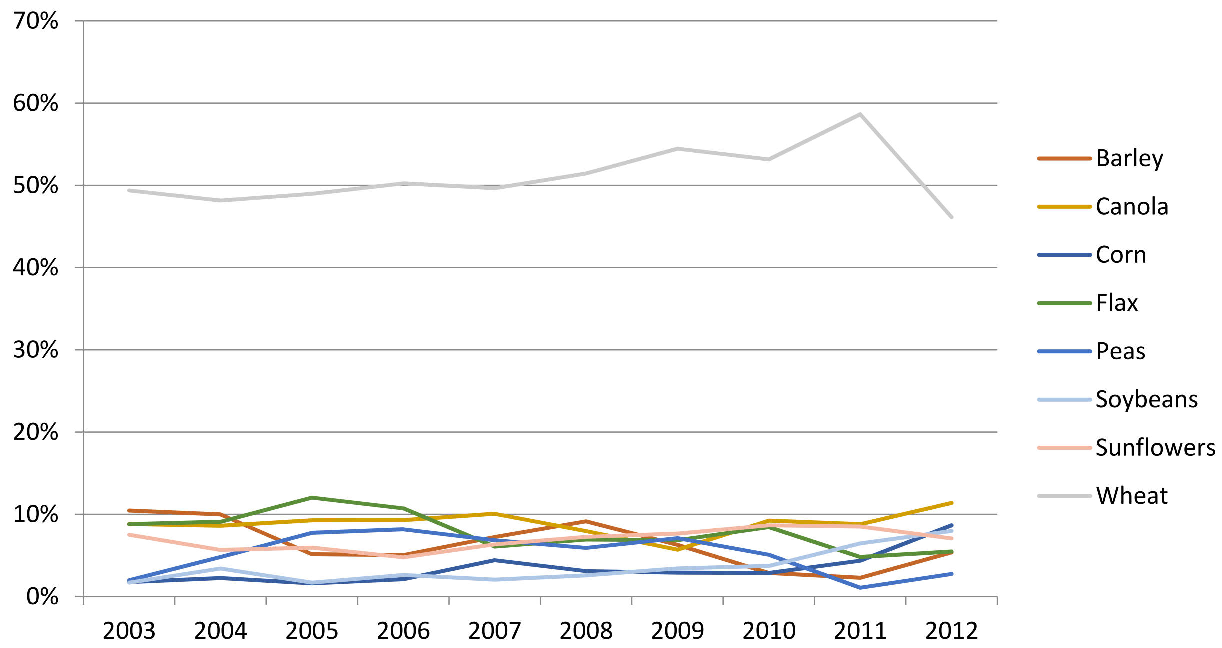

Figure 1. Acres Planted, McLean and Sheridan Counties
Source: Farm Service Agency, USDA

Representative dryland and irrigated crop budgets were constructed; the dryland rotations are

- spring wheat-canola-spring wheat-soybean
- corn-soybean-spring wheat
- corn-dry bean-spring wheat.

Four irrigated rotations are

- primarily corn
- corn-corn-dry bean-spring wheat
- corn-dry bean-barley-beets
- corn-dry bean-barley-potatoes.

The primarily corn rotation may be better understood as predominantly corn, recognizing that producers are likely to plant another crop occasionally, but not frequently enough to significantly impact the budget for the rotation.

Traditional Crop Budgets

The three representative dryland rotations were identified to provide an understanding of potential returns. Data from the North Central North Dakota Projected 2014 Crop Budgets (Appendix I) were used to calculate the revenue, costs, and returns to management for each rotation on a composite acre basis (Table 2). The budgets were constructed on a composite acre basis using expected yields, expected 2014 crop prices, and anticipated production costs in 2014 (Swenson and Haugen 2014).

Table 2. Baseline Dryland Rotations Revenue, Costs, and Returns Per Acre

	HRS/Canola/ HRS/Soybean	Corn/Soybean/ HRS	Corn/Dry Bean/ HRS
Revenue	$284.92	$315.17	358.05
Direct Costs	160.81	187.13	207.25
Indirect Costs	88.67	94.32	98.37
Total Cost	249.48	281.45	305.62
Return to Labor and Management	$35.44	$33.72	$52.53

Source: Swenson and Haugen, 2014

Of the three rotations, the corn-dry bean-spring wheat rotation had the highest estimated returns for 2014. The rotations used in the analysis are based on the assumption that producers follow production practices that make agronomic and economic sense.

Revenue, costs, and returns per acre for alternative irrigated rotations are presented in Table 3. Detailed irrigated budgets by crop are presented in Appendix II, including an $18 per acre water/irrigation service charge. The cost of irrigation is estimated using a model develop by Aakre (2013) and is included in Appendix III.

The level of selected inputs (e.g., nitrogen fertilizer for corn) is increased to match the higher target yield of irrigated crops. Gross revenue, costs, and net returns were greatest for the rotation with potatoes. A crop rotation consisting of 25 percent potatoes was estimated to have a net return of $611 per acre. A rotation of primarily corn was estimated to have a net return around $92 per acre; the crop rotation including sugar beets (for industrial purpose) was estimated to have a net return of approximately $136 per acre; and the return for an irrigated rotation of corn, dry beans and wheat was estimated to be $115 per acre (Table 3).

The returns to labor and management for the composite irrigated acre (that is, the irrigated crop rotations) exceed the returns for the composition dryland acre; this difference is observed by comparing the results of Tables 2 and 3. However, the return to irrigated crops is conservative. For example, the useful life of installed irrigation infrastructure may be much longer than the 20 years used to calculate depreciation.

Table 3. Baseline Irrigated Rotations Revenue, Costs, and Returns Per Acre

	Primarily Corn	Corn/Corn/ Dry Bean/Wheat	Corn/Dry Bean/ Barley/Beets	Corn/Dry Bean/ Barley/Potatoes
Revenue	$640.00	$608.45	$715.25	$1,449.25
Direct Costs	$331.12	$283.27	$342.74	$608.57
Indirect Costs	$216.73	$209.90	$236.53	$229.82
Total Cost	$547.85	$493.17	$579.27	$838.39
Return to Labor and Management	$92.15	$115.28	$135.98	$610.86

Another consideration or risk associated with irrigation is the long term availability of water. If the project is fully developed, it would likely need less than 45,000 acre-feet of water annually. To put that quantity into perspective: given an average mean flow rate of 23,170 cubic feet per second between 1954 and 2000, less than one day's volume of water from the Missouri River would be used annually by this 51,700-acre project. An assured availability of water, although not quantified in this analysis, reduces the risk of investing in developing irrigation. If there is an uncertainty as to the availability of water (such as a limited surface source or a minimal aquifer as is being experienced in other regions of the United States), the willingness to invest in irrigation would likely be diminished. The Missouri River and McClusky canal virtually eliminate the risk of not having water available for this project.

The dryland spring wheat-canola-spring wheat-soybean rotation[2] was selected for this analysis as it includes the three most prevalent crops in the region, based on USDA Farm Service Agency data (Figure 1 and Table 2). Primarily irrigated corn (Table 3) was used as the crop because it is readily marketable and does not require specialty processors as is the case with beets and potatoes (however, potatoes in the study region would almost certainly be competitive with potato production in other areas of the state that supply existing processing facilities in central and eastern North Dakota).

- Corn-corn-dry bean-spring wheat irrigated rotation provide a greater return than a rotation of primarily irrigated corn (Table 3); but if the project is feasible with a conservative primarily irrigated corn rotation, it is more feasible with an irrigated crop rotation projected to generate a greater return.
- Some potatoes are being grown on land irrigated as part of the "Mile Marker 7.5" project. These acres are likely being incorporated into the rotation of irrigated land in nearby counties. Potatoes are clearly possible but, again, if the project is feasible with a conservative (i.e., primarily corn) rotation, it should certainly be feasible with alternative crop rotations that generate greater returns.[3]
- The beet rotation is perhaps best considered infeasible until a market for the commodity (such as processing the beet into an industrial sugar) arises in central North Dakota.

Irrigation reduces low yields resulting from inadequate moisture; irrigation does not address other causes of low yields such as excess moisture, cool growing conditions, early freezes, hail, or disease. Accordingly, the yields and economic returns for irrigation will not always be the maximum because the yields remain subject to adverse conditions during the growing season other than lack of moisture. This phenomenon is apparent from the irrigated yields summarized in Table 1.

It also should be noted that the comparison is a dryland rotation of hard red spring wheat, soybeans, and canola to irrigated corn (Tables 2 and 3; $35 versus $92) and is not a comparison between dryland corn and irrigated corn (Appendix I and Table 3; $2 versus $92), for example. A rotation of dryland crops in an arid region (such as central North Dakota) achieves some risk reduction and thus reduces the beneficial gain of producing a single irrigated crop.

[2] The selected dryland rotation is 50% spring wheat, 25% canola, and 25% soybean.
[3] A more aggressive irrigated rotation of 67% corn, 5% potato, 9% dry bean, and 19% soybean could annually generate an additional $190.50 net return per acre relative to a dryland rotation of 50% spring wheat, 25% canola, and 25% soybean.

Stochastic Crop Budgets

Stochastic crop budgets that incorporate production risk in the form of variable yields are constructed to analyze returns to dryland and irrigated production. The first step is to fit a model to historical crop yields.

Time Series Analysis

@Risk software was used to identify and fit the best time series function form for each crop and estimate the correlation between them. Fit statistics and parameters are presented in Table 4. Each crop was best fit using a moving average 1 (MA1) model. The Akaike Information Criterion (AIC) measures the goodness of fit, mu is the mean of the process, sigma measures volatility, and b1 is the first order coefficient.

Restated, the information in Table 4 indicates how well the model fits historical data. The analytical method identifies the model that best fits the data.

- It is a coincident that all six crop yields are best projected using the same model (MA1).
- The methodology then determines whether the yields over time reveal a trend, especially an upward or downward trend in the yield. For five crops (dryland spring wheat, dryland canola, dryland soybean, irrigated dry bean and irrigated spring wheat), the analytical method detected no upward or downward trend; the results can it be described as detecting a trend of "flat" yields. For the sixth crop (irrigated corn), the analytical method detected a relatively constant upward trend, described as a First Order trend.

Table 4. Time Series Model Fit

	Dryland			Irrigated		
	Spring Wheat	Canola	Soybean	Corn	Dry Bean	Spring Wheat
Model Type	MA1	MA1	MA1	MA1	MA1	MA1
Detrended	No	No	No	First Order	No	No
Mu	58.8	2864.4	38.8	2.9	2484.4	77.6
Sigma	17.5	488.0	10.2	35.1	515.2	8.5
b1	0.2	0.9	0.7	-1.0	-0.9	-0.9

The remaining three rows in table 4 indicate the volatility among the yields for these six crops.

- Mu for five crops is the average projected yield (bushels or pounds). The Mu for irrigated corn (which showed a "First Order" trend) reveals an average increase in corn yields; that is, three (3) bushels annually. Again, there is no upward trend in the yields for the other five crops.
- Sigma is the variation in yields.
- The b1 values for the first three crops indicate there is a slight upward trend in the yields. Data for the remaining crops were insufficient to detect a trend in yields even though yields have trended upward for decades.

Overall, Table 4 indicates that the analytical method projects future yields in a manner that researchers and others can be confident in the results. Perhaps the most important observation is that the model projects a relatively flat trend for the future yield in all crops analyzed except an upward trend of three bushels annually for corn.

The correlations between the crops' yield are presented in Table 5. There is a relatively strong positive relationship between dryland spring wheat and dryland canola yields; that is, when spring wheat yields are high (low), so are those for canola. The relationship between dryland yields and irrigated primarily corn is weak with the strongest (albeit, negative) correlation between canola and irrigated corn yields (-0.385). Restated, conditions that cause irrigated corn to yield more are likely to cause a reduction in canola yields.

There also appears to be strong positive correlation between irrigated corn and irrigated dry beans and a strong negative correlation between irrigated corn and irrigated wheat, and between irrigated dry beans and irrigated wheat. The analysis reveals a strong positive relationship between dryland wheat and irrigated wheat, and between dryland canola and irrigated wheat. All of these relationships show that wheat does not respond well to irrigation, a long-standing observation, and that dry beans and corn both demonstrate a positive response to irrigation.

More detailed information about the results of the time series analysis is presented in Appendix IV.

It is assumed that irrigation would reduce risk but, as stated previously, the analysis does not show as much difference in risk between the dryland crop rotation and the irrigated crop rotation as may be intuitively expected. The primary reason for this somewhat unexpected result is because the analysis is comparing a dryland rotation of three crops to an irrigated rotation of one crop. The data in Table 5 (more specifically, the limited correlation between dryland soybeans and the other dryland crops, versus the small negative correlation between irrigated corn and dryland crops) reveals that a diversity of dryland crops in an arid region (such as central North Dakota) achieves some of the same risk reduction as irrigating a single crop.

Table 5. Crop Yield Correlation Matrix

	Dryland			Irrigated		
	Spring Wheat	Canola	Soybean	Corn	Dry Bean	Spring Wheat
Spring Wheat	1					
Canola	0.646	1				
Soybean	-0.051	0.275	1			
Irr. Corn	-0.028	-0.385	0.187	1		
Irr. Dry Bean	-0.034	0.128	0.450	0.625	1	
Irr. Spring Wheat	0.775	0.489	-0.396	-0.430	-0.525	1

Simulation

Using the fit time-series models and crop yield correlations, a simulation was conducted using @Risk Software to determine the impact of crop yield variation on returns to dryland and irrigated production. Detailed results of the simulations are presented in Appendix V. Crop and input prices are held constant as the simulation was run 10,000 times. Yields are presented in Table 6. For dryland wheat, yields were 89 bushels per acre or higher for 5% of the time (about once in twenty years). However 10 percent of the time, yields are expected to be 34 bushels or lower. The model does not directly account for the reason yields may be low (or high), but may include excess moisture, drought, inadequate growing degree days, freeze, hail, or disease.

Table 6. Expected Crop Yields (2014)

	Dryland			Irrigated		
	Spring Wheat	Canola	Soybean	Corn	Dry Bean	Spring Wheat
	(bushels)	(pounds)	(bushels)	(bushels)	(pounds)	(bushels)
Best Year in 20	89	3,112	48	228	2846	95
Best Year in 10	82	2,946	44	215	2659	92
Average Year	58	2,316	31	171	1998	81
Worst Year in 10	34	1,687	18	127	1338	70
Worst Year in 20	28	1,514	14	114	1151	67

Crop yields were used to estimate the revenues and returns for individual crops and rotations. The results of these analyses are presented in Tables 7 and 8, respectively. Spring wheat returns vary from $353 per acre during the best year in 20 to losing $60 per acre during the worst year in 20. It is notable that in the worst year in 20, canola returns are positive. This is because canola yields during the trials were high and showed relatively little variability (Table 1). Again, these returns are driven by variation in yield which may be the result of weather or pests.

Table 7. Stochastic Returns to Management and Labor (per Acre) for Selected Crops and Rotations (2014)

	Spring Wheat	Canola	Soybean	Dryland Rotation*	Irrigated Corn	Irrigated Corn/ Dry Bean/HRS
Best Year in 20	$353	$380	$283	$272	$365	$276
Best Year in 10	$310	$345	$244	$246	$313	$244
Average Year	$148	$213	$101	$153	$137	$140
Worst Year in 10	-$13	$81	-$43	$60	-$39	$36
Worst Year in 20	-$60	$44	-$83	$33	-$91	$15

* A dryland rotation of HRS/Canola/HRS/Soybean

Returns to dryland rotations varied from $272 to $33 (Table 7 or 8) while irrigated corn varied from $365 to -$91 (Tables 7 or 8). In the average year (when realized yields are at their mean), irrigated corn returns $16 less per acre than the representative dryland rotation. Restated, after all costs have been accounted for (including all costs of irrigation), irrigated corn is expected to return $16 less per acre than the dryland rotation. The difference in average expected returns, -$16, is much less than the $57 (92.15 - 35.44) difference calculated using the baseline dryland and irrigated budgets (Tables 2 and 3). This occurs because the dryland trial yields (Table 1 which were used in preparing Tables 7 and 8) are significantly higher than the dryland yields provided in the budget projections (Appendix I which was used in preparing Table 2).

Table 8. Stochastic Returns to Management and Labor by Rotation (per Acre; 2014)

	Dryland Rotation	Irrigated Corn	Irrigated Corn/ Dry Bean/HRS	Dryland -- Irrigated Corn Difference	Dryland -- Irrigated Corn/Dry Bean/HRS Difference
Best Year in 20	$272	$365	$276	$240	$186
Best Year in 10	$246	$313	$244	$183	$144
Average Year	$153	$137	$140	-$16	$4
Worst Year in 10	$60	-$39	$36	-$215	-$138
Worst Year in 20	$33	-$91	$15	-$280	-$171

The “Dryland-Irrigated Corn Difference” column (Table 8) presents the difference between returns for dryland and irrigated corn rotations in the same year. The difference is $240 every 20 years. Again this is the difference within the same year. The ‘Dryland-Irrigated Corn/Dry Bean/HRS Difference” column presents the difference between dryland and irrigated corn-dry bean-hard red spring rotations in the same year.

The results may underestimate the returns to irrigation. First as already described, the historical canola data may not be representative. Second, trend-line increases in irrigated corn yields, which average about three bushels per acre per year, are not considered.

Projecting Future Yields

The time series analysis found that yields increased for irrigated corn on average 2.9 bushels per year across observed period, but did not for other crops. Projecting this increase ten years into the future the average yield for irrigated corn would increase from 171 (Table 6) to 200 bushels per acre. Holding crop and input prices and input levels constant would mean an increase in average returns from $137 (Table 7) to $253 per acre. The difference between average stochastic dryland and stochastic primarily irrigated corn would increase from -$16 to $100 per acre.

Increasing fertilizer use in proportion to the increased yield (17%) would increase fertilizer expenses from $117 to $136 per acre. A 10% increase in fuel and repair expenses and machinery depreciation and interest, and a proportional increase (17%) in drying expenses, would increase costs $12.86. Incorporating these expenses would reduce the difference in returns between dryland and irrigated production from $100 to $68 per acre. Irrigated corn becomes more profitable with the passage of time due to the projected increase in future corn yields exceeding the projected increase in future yields of other crops.

Impact on Land Values

Assuming that the per acre cost of labor and management for dryland and irrigated production is the same, and that land is the most limiting factor, the difference in net returns can be capitalized in the price of land. Given a capitalization rate of 4%, the $56.71 difference in baseline dryland ($35.44) and irrigated ($92.15) returns increases the value of land by $1,418 per acre.

The -$16 difference between the 2014 dryland and irrigated corn rotation would lead to no adoption and no change in the capital price of land. The $68 increase in returns for 2024 rotations would increase the value of land by $1,700 per acre. Across 51,700 acres, this totals to an increase in land value of more than $87.9 million.

Conclusion

The purpose of this study is to estimate farm-level returns to irrigation to gauge farmer willingness to invest in irrigation and produce irrigated crops, and to provide inputs for a second study that estimates state-level economic effects of expanded irrigation.

Farm-level returns are estimated using traditional enterprise budgets as well as stochastic budgets which account for variability in crop yields. The stochastic budgets require knowledge of the distribution of crop yields which are estimated using historical crop yields. Irrigated continuous corn and dryland rotations of soybean-canola-spring wheat were selected as representative rotations for comparison.

Based on average dryland and irrigation yields, the annual benefit of irrigation to the farm operator is $56.71 (92.15-35.44) per acre. A capitalization rate of four percent indicates that the value of irrigable land increases $1,418 (56.71/.04) per acre.

However, average yields do not acknowledge the impact of varying yields. A stochastic analysis of data from the North Dakota State University Research Extension Centers at Carrington for irrigation yields and Minot for dryland yields was conducted to determine the impact of varying dryland and irrigated yields.

Trial yield data from recent years suggest that the benefit of irrigating is less (as much as $72 per acre less, i.e., $56 compared to -$16) than the benefit of irrigation as calculated by analyzing average yields. However, this outcome reflects the moist conditions in north central North Dakota in recent years, that irrigation does not eliminate other production risks, such as disease, temperature, or excess moisture, and the experience that trial plot yields often exceed yields in fields. Consequently, the benefit of irrigation appears less.

If the irrigated crop will primarily be corn, the analysis can consider the yield trends which give corn an advantage. Restated, corn yields indicate a greater upward trend than other crop yields (especially those crops that are grown without irrigation). The benefit of irrigating a rotation that is primarily corn increases the value of irrigable land by $1,700 (68/.04) per acre over the next decade. The benefit of irrigating also will increase if precipitation in central North Dakota returns to conditions experienced prior to the past two decades.

Irrigation is more than adding moisture to a growing crop; it is about managing water. Irrigation permits operators to apply water as corn is pollinating or when moisture is needed for potatoes, for example. The benefits of being able to manage moisture for a growing crop are not explicitly quantified in this analysis.

The -$16 difference between the 2014 dryland and irrigated corn rotation would lead to no adoption and no change in the capital price of land. The increase to $68 in returns for 2024 rotations would increase the value of land by $1,700 per acre. Across 51,700 acres, this totals to an increase in land value of approximately $87.9 million.

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Appendix I. Dryland Crop Budgets

The following table provides yield, price, line item costs, and return to labor and management projected for central North Dakota for selected dryland crops in 2014.

	Barley	Durum	HRS	Corn	Soybeans	Drybeans	Flax	Canola	Sunflower (Oil)	Sunflower (Confection)
Yield	59	36	39	92	29	1430	20	1460	1500	1450
Price	5.15	7.05	6.74	4.00	10.85	0.31	12.94	0.21	0.21	0.31
Revenue	303.85	253.80	262.86	368.00	314.65	443.30	258.80	299.30	313.50	448.05
Direct Costs										
Seed	16.50	22.50	18.38	71.00	69.60	45.00	13.30	48.50	29.82	44.10
Herbicide	23.50	26.00	26.00	20.00	20.00	45.30	28.30	20.50	32.90	35.00
Fungicide	5.50	5.50	5.50	-	-	-	-	-	-	-
Insecticide	-	-	-	-	-	-	-	-	7.00	14.00
Fertilizer	49.23	48.24	53.60	67.40	6.81	36.05	26.18	63.12	38.00	36.20
Crop Insurance	15.00	13.20	13.19	26.56	11.94	21.84	9.40	10.82	11.72	16.41
Fuel and Lubrication	19.02	17.38	17.61	25.56	14.48	20.40	16.32	17.66	19.60	19.48
Repairs	18.00	17.54	17.62	21.69	15.71	20.75	17.35	17.68	18.26	18.22
Drying	-	-	-	19.32	-	-	-	-	4.50	4.35
Miscellaneous	1.50	1.50	1.50	1.50	4.75	12.75	1.50	1.50	9.50	17.50
Operating Interest	3.13	3.23	3.26	5.38	3.04	4.29	2.39	3.82	3.64	4.36
Total	151.38	155.09	156.66	258.41	146.33	206.38	114.74	183.60	174.94	209.62
Indirect Costs										
Misc. Overhead	7.34	6.96	7.02	9.15	6.51	7.71	6.73	7.00	7.62	7.59
Mach. Depreciation	21.05	20.07	20.22	30.75	19.05	25.83	19.50	20.60	22.58	22.50
Mach. Investment	12.23	11.74	11.81	17.38	10.46	14.64	11.47	12.15	13.56	13.52
Land Charge	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20
Total	90.82	88.97	89.25	107.48	86.22	98.38	87.90	89.95	93.96	93.81
Total Cost	242.20	244.06	245.91	365.89	232.55	304.76	202.64	273.55	268.90	303.43
Return to Labor and Management	**61.65**	**9.74**	**16.95**	**2.11**	**82.10**	**138.54**	**56.16**	**25.75**	**44.60**	**144.62**

Source: NDSU North Central Crop Budgets 2014

Appendix II. Irrigated Crop Budgets

The following table provides yield, price, line item costs, and return to labor and management projected for central North Dakota for selected irrigated crops in 2014. Machinery depreciation is incorporated into the machinery investment category for irrigated potato and beet production.

	BARLEY	HRS	CORN	SOYBEANS	DRY BEANS	POTATOES	BEET	ALFALFA*
Yield	100.0	70.0	160.0	55.0	2200.0	360.0	32.0	5.0
Price	5.15	6.74	4.00	10.85	0.31	11.00	32.00	100.00
Revenue	515.00	471.80	640.00	596.75	682.00	3960.00	1024.00	500.00
DIRECT COSTS								
-Seed	16.50	18.38	71.00	69.60	45.00	368.26	82.47	16.88
-Herbicides	23.50	26.00	20.00	20.00	45.30	73.07	116.78	4.93
-Fungicides	5.50	5.50	0.00	0.00	0.00	113.59	0.00	0.00
-Insecticides	0.00	0.00	0.00	0.00	0.00	80.53	0.00	0.00
-Fertilizer	83.44	96.21	117.22	12.92	55.46	350.53	108.40	60.29
-Crop Insurance	15.00	13.19	26.56	11.94	21.84	78.00	35.00	0.00
-Fuel & Lubrication	19.02	17.61	25.56	14.48	20.40	67.65	64.77	27.22
-Repairs	18.00	17.62	21.69	15.71	20.75	79.13	104.67	19.67
-Irrigation Power	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86
-Irrigation Repairs	13.03	13.03	13.03	13.03	13.03	13.03	13.03	13.03
-Drying	0.00	0.00	19.32	0.00	0.00	0.00	0.00	0.00
-Miscellaneous	1.50	1.50	1.50	4.75	12.75	356.94	23.00	5.98
-Operating Interest	3.13	3.26	5.38	3.04	4.29	55.41	24.72	5.62
Total	208.48	222.16	331.12	175.33	248.68	1,646.00	582.70	163.46
INDIRECT (FIXED) COSTS								
Misc. Overhead	7.34	7.02	9.15	6.51	7.71	18.00	30.00	6.00
Machinery Depreciation	21.05	20.22	30.75	19.05	25.83			44.01
Machinery Investment	12.23	11.81	17.38	10.46	14.64	117.39	132.23	28.19
-Irrigation Service	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
-Irrigation Depreciation	57.03	57.03	57.03	57.03	57.03	57.03	57.03	57.03
-Irrigation Investment	34.22	34.22	34.22	34.22	34.22	34.22	34.22	34.22
-Land Charge	50.20	50.20	50.20	50.20	50.20	50.20	50.20	50.20
Total	200.07	198.50	216.73	195.47	207.63	294.84	321.68	185.88
Total Costs	408.55	420.66	547.85	370.80	456.31	1940.84	904.38	558.97
RETURN TO LABOR & MANAGEMENT	**106.45**	**51.14**	**92.15**	**225.95**	**225.69**	**2019.16**	**119.62**	**-58.97**

*Four-year average costs (seeding in first year)

Based on Central Irrigated Budgets 2014 and North Central Crop Budgets, NDSU

Appendix III. Irrigation Operating Expenses

The following table summarizes the economic cost of irrigation based on a) equipment purchase cost and expected useful life, b) operating costs of applying water, and c) irrigation equipment maintenance cost.

Irrigation Investment Assumptions			
Center Pivot	$70,000	Salvage Value	20%
Freight, Installation, Pad, Fittings	9.000	Average years of life	20
Pipe and Power	34,918	Total Depreciation	$145,996
Off-Farm Cost Share	68,577	Average annual investment	$109,497
Total Investment	$182,495*		
Irrigation Operating Assumptions			
Pivot Acres	128	kwh/hr	22.5
Inches Pumped	10	$/kwh	$0.080
Operating Hours	701		

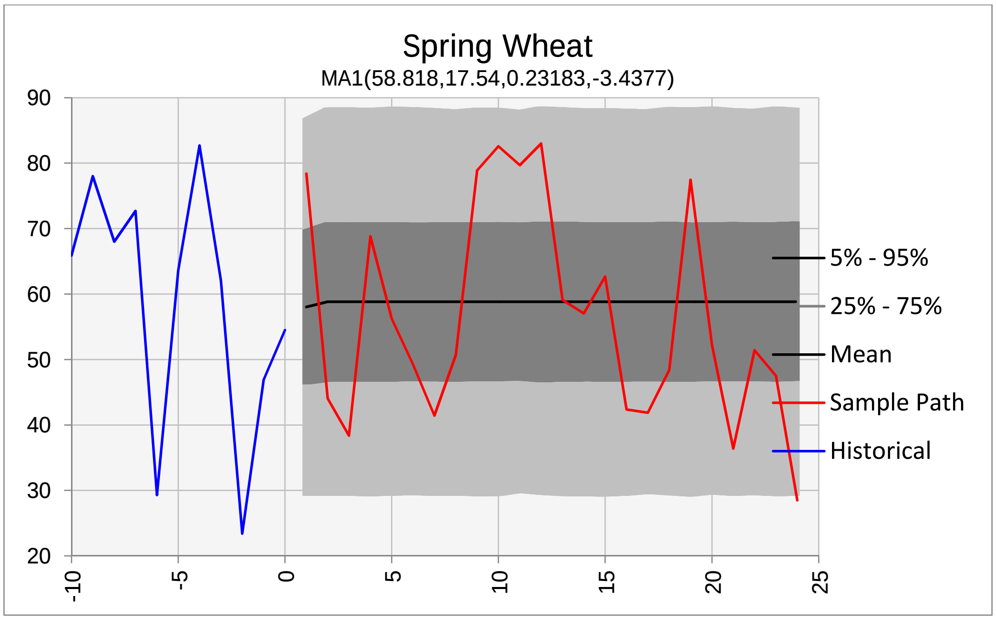
	Per hour	Annual Total	Per Acre
Irrigation Investment cost @ 4.0%			$34.22
Irrigation Depreciation cost			$57.03
Irrigation Repairs	Per hour	Annual Total	Per acre
-- Power unit	$0.57	$399.57	$3.12
-- Delivery system	$1.74	$1,219.74	$9.53
-- Oil/electric motor	$0.07	$49.07	$0.38
Total Irrigation Repairs			$13.03
Irrigation Power	$1.80	$1,261	$9.86

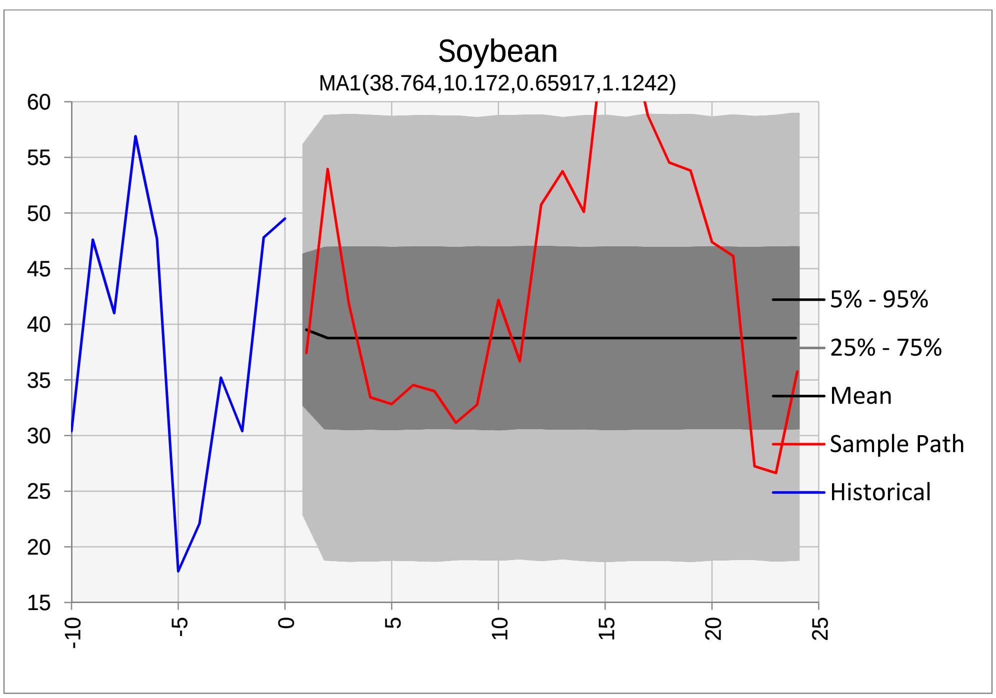
*These investment amounts do not include the cost of installing electrical power to the site.
Based on Central Irrigated Budgets 2014, NDSU

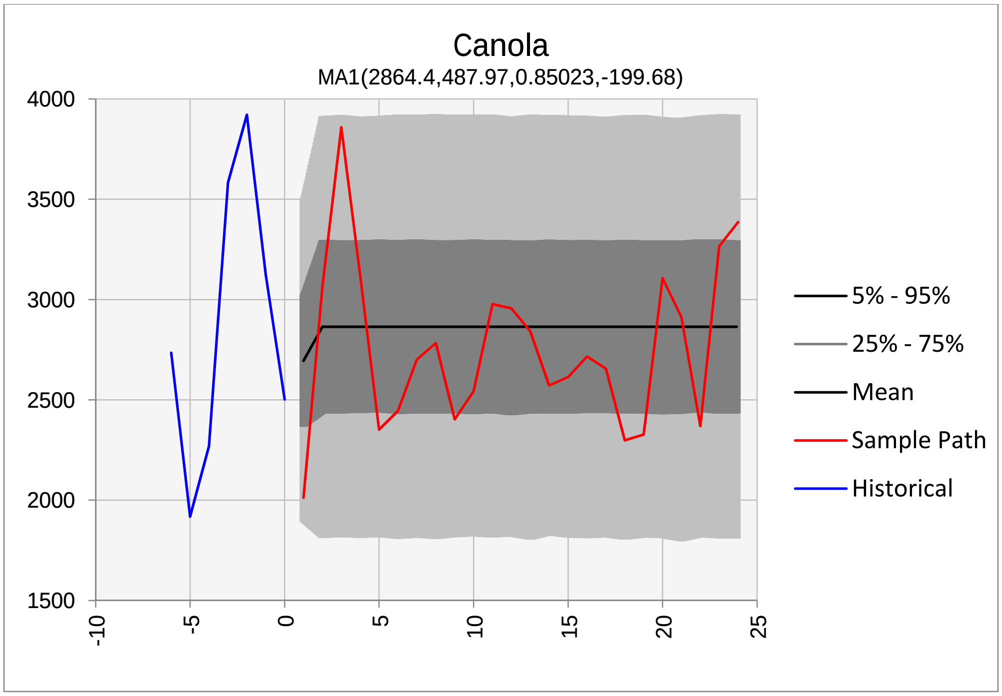
Appendix IV. Time Series Analysis

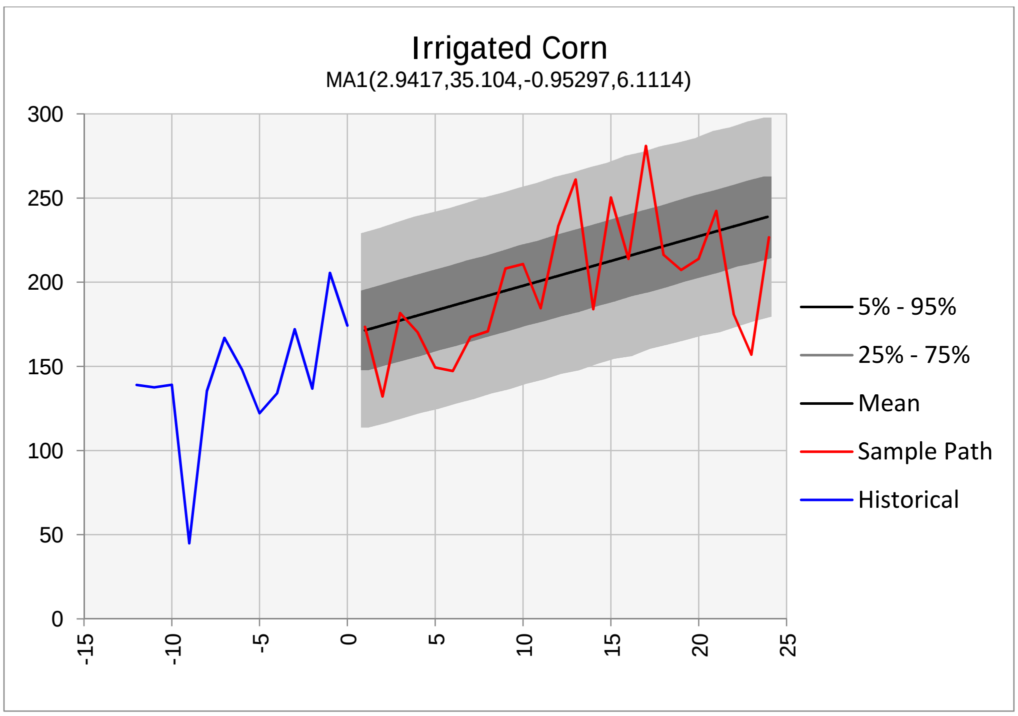
This appendix presents the results of the time series analysis including estimated parameters and 20 years of simulated yields using trial data from the Carrington and Minot Research Extension Centers. A Moving Average 1 model had the best fit for all crops based on the Akaike Information Criterion.

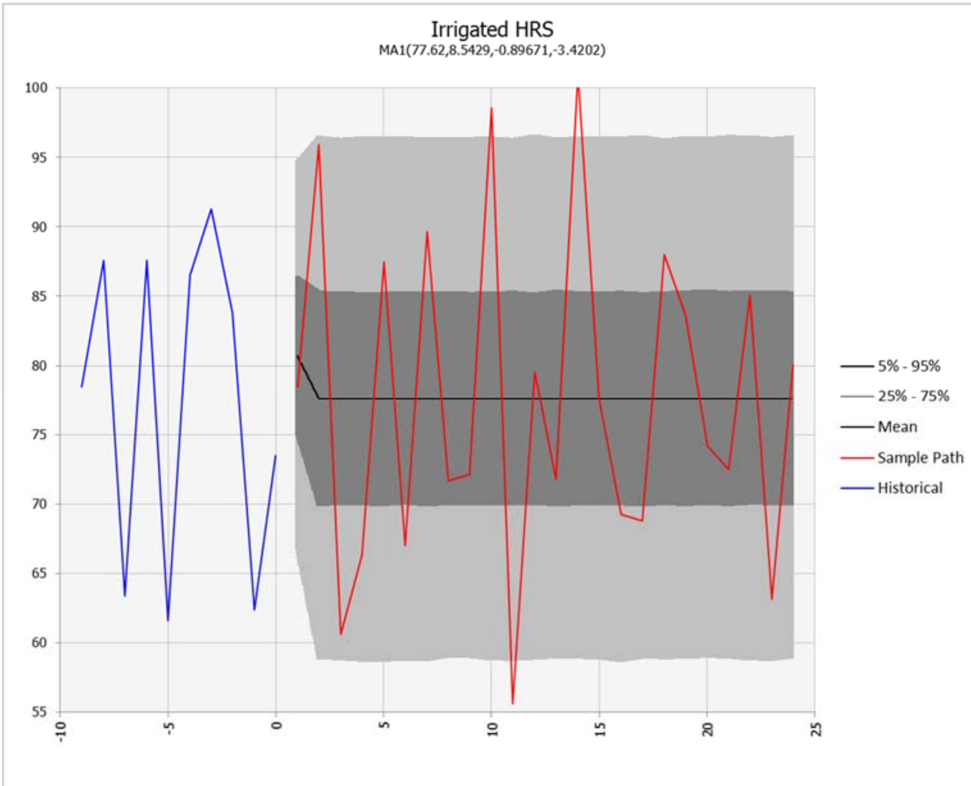
Spring wheat yields averaged 58.8 bushels per acre with a standard deviation of 17.54. Simulated values ranged from 29 to 83 bushels per acre.



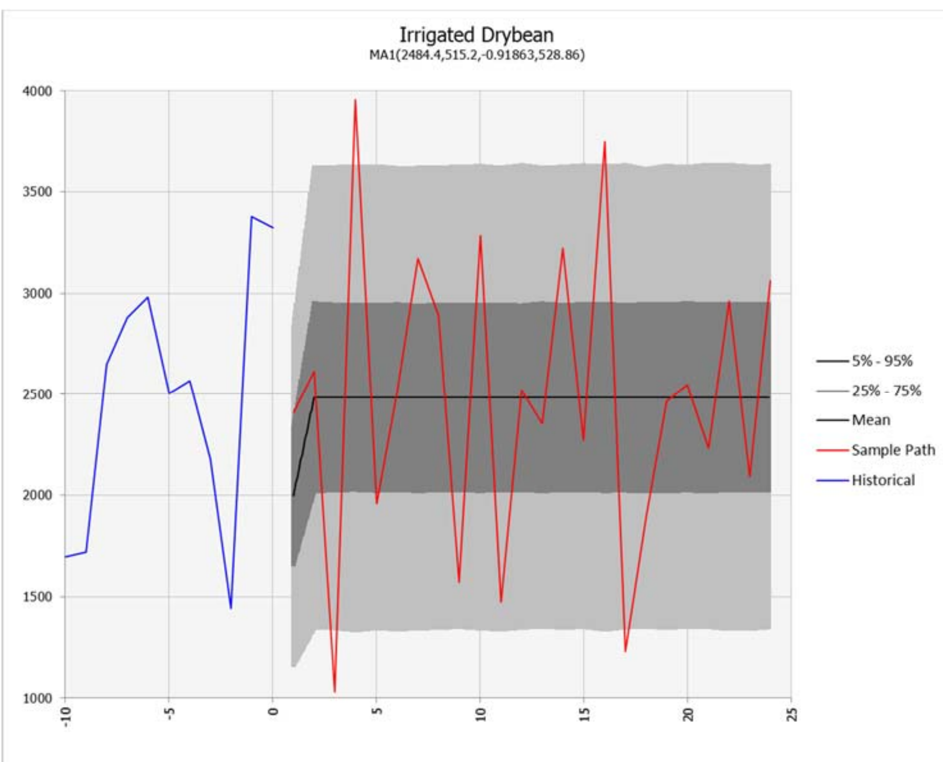



Canola
MA1(2864.4,487.97,0.85023,-199.68)
4000
3500
3000
2500
2000
1500
-10
-5
0
5
10
15
20
25
5% - 95%
25% - 75%
Mean
Sample Path
Historical


Irrigated Corn
MA1(2.9417,35.104,-0.95297,6.1114)
300
250
200
150
100
50
0
-15
-10
-5
0
5
10
15
20
25
5% - 95%
25% - 75%
Mean
Sample Path
Historical



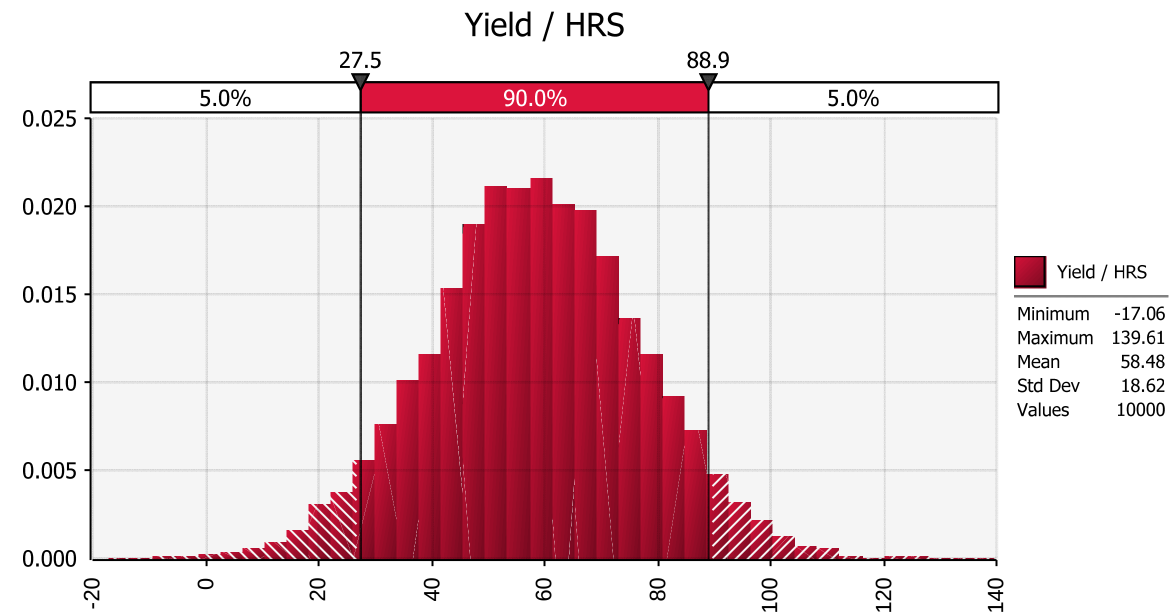
Irrigated HRS
MA1(77.62,8.5429,-0.89671,-3.4202)
100
95
90
85
80
75
70
65
60
55
-10
-5
0
5
10
15
20
25
5% - 95%
25% - 75%
Mean
Sample Path
Historical

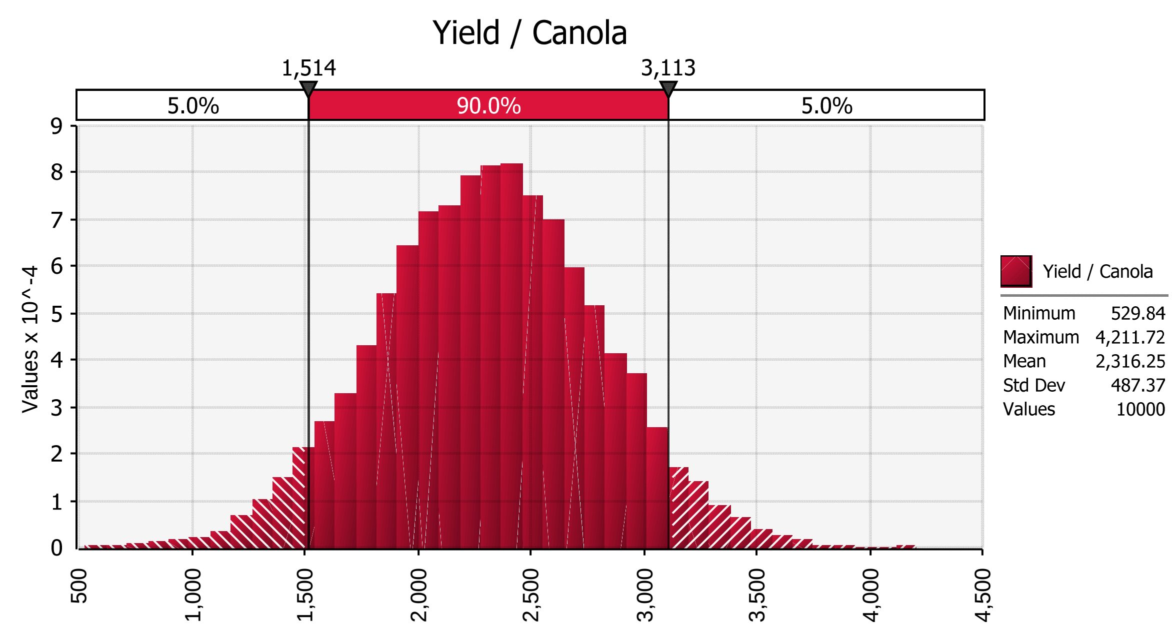


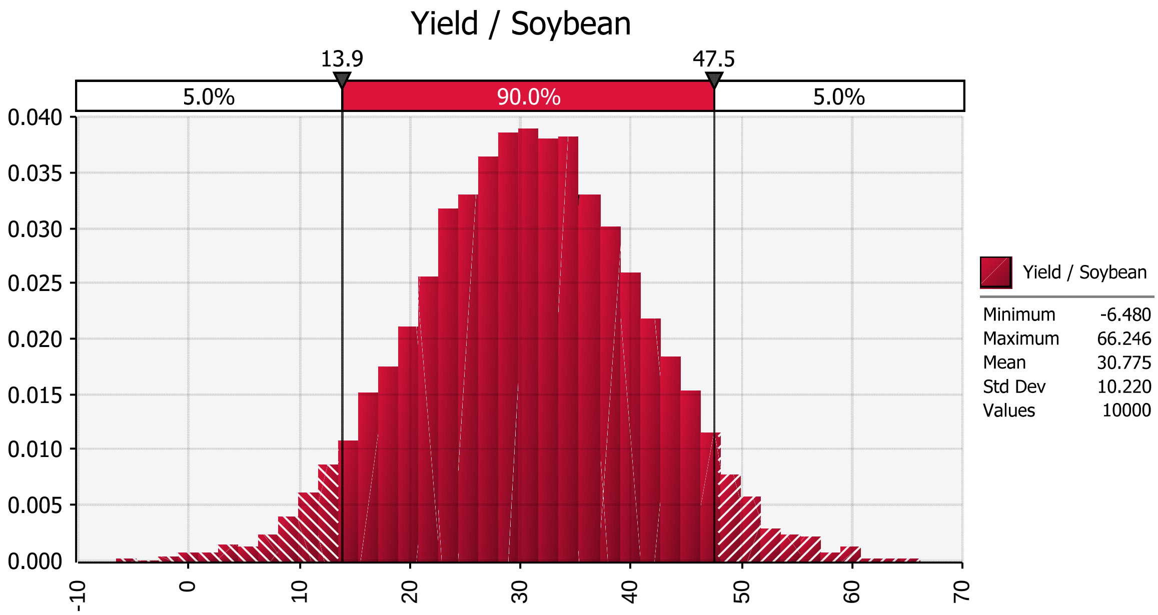
Irrigated Drybean
MA1(2484.4,515.2,-0.91863,528.86)
4000
3500
3000
2500
2000
1500
1000
-10
-5
0
5
10
15
20
25
5% - 95%
25% - 75%
Mean
Sample Path
Historical

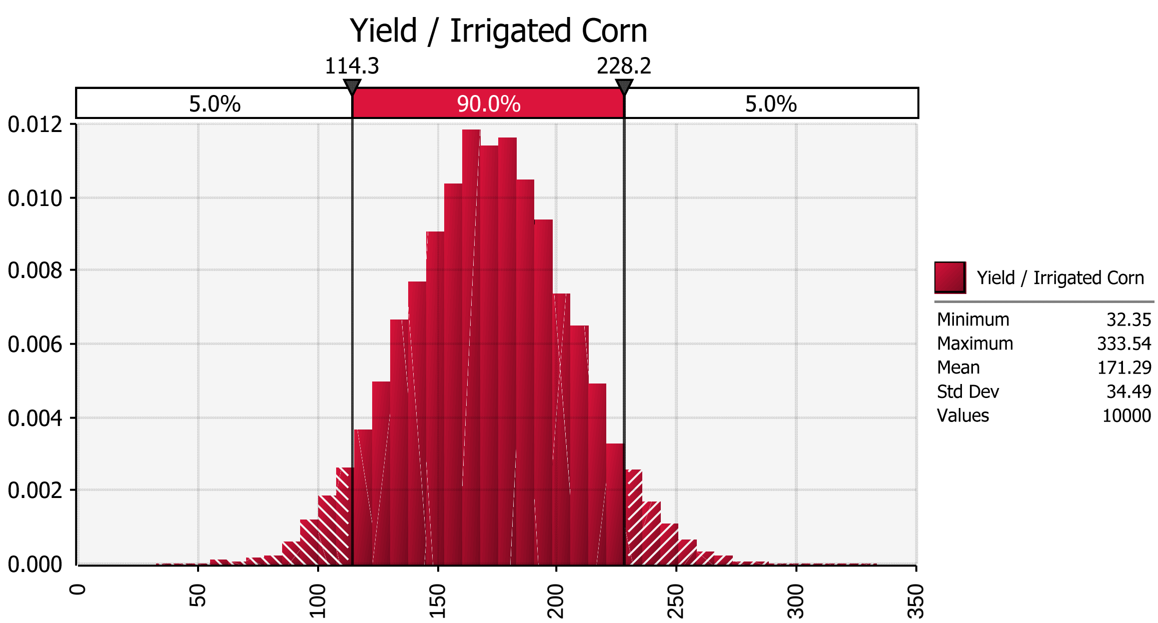
Appendix V. Simulation Results

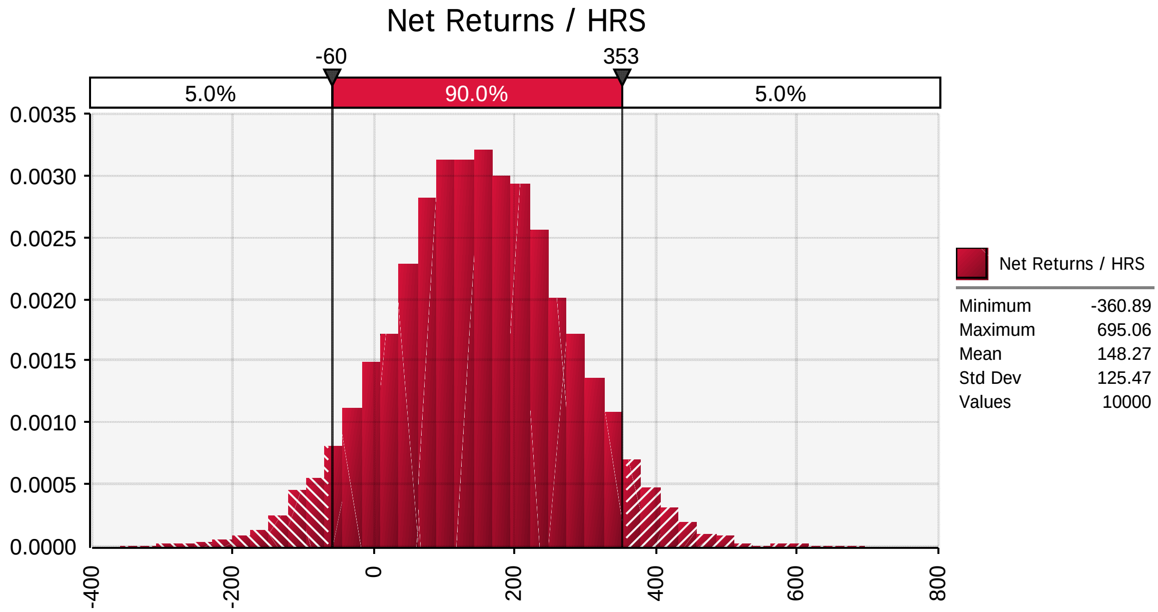
Yields were simulated for each crop using parameters estimated by the time series analysis presented in Appendix IV. The first chart presents the results of 10,000 draws of spring wheat yields based on trial data. The average simulated yield was 58.48 bushels per acre. 90 percent of simulated yields fell between 27.5 and 88.9 bushels per acre.

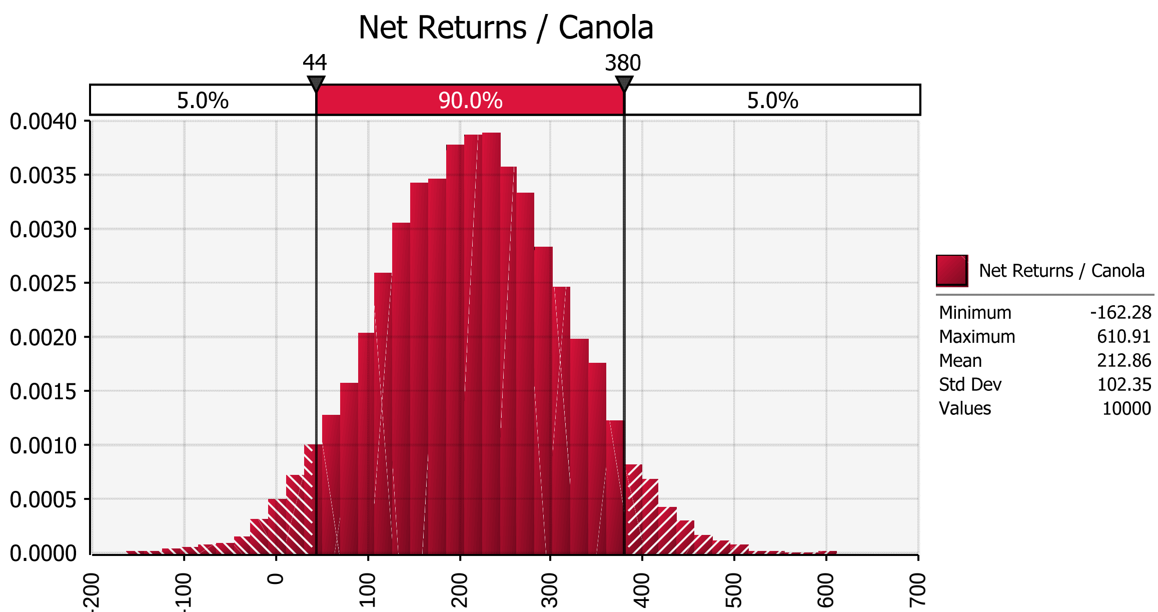


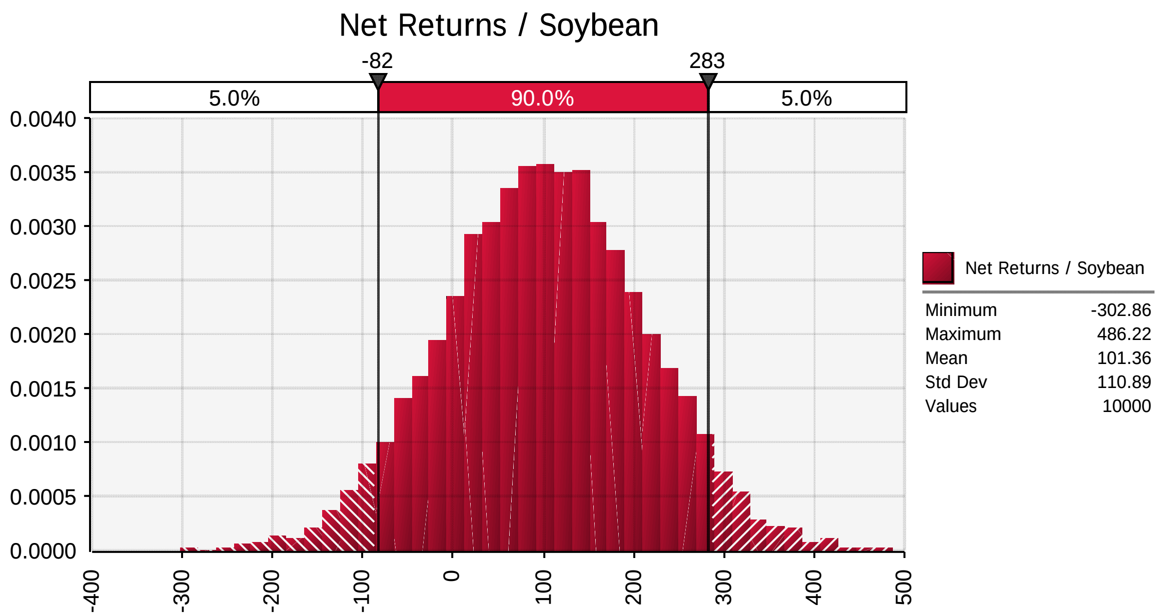



Yield / Soybean
13.9
47.5
5.0%
90.0%
5.0%
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-10
0
10
20
30
40
50
60
70
Yield / Soybean
Minimum -6.480
Maximum 66.246
Mean 30.775
Std Dev 10.220
Values 10000

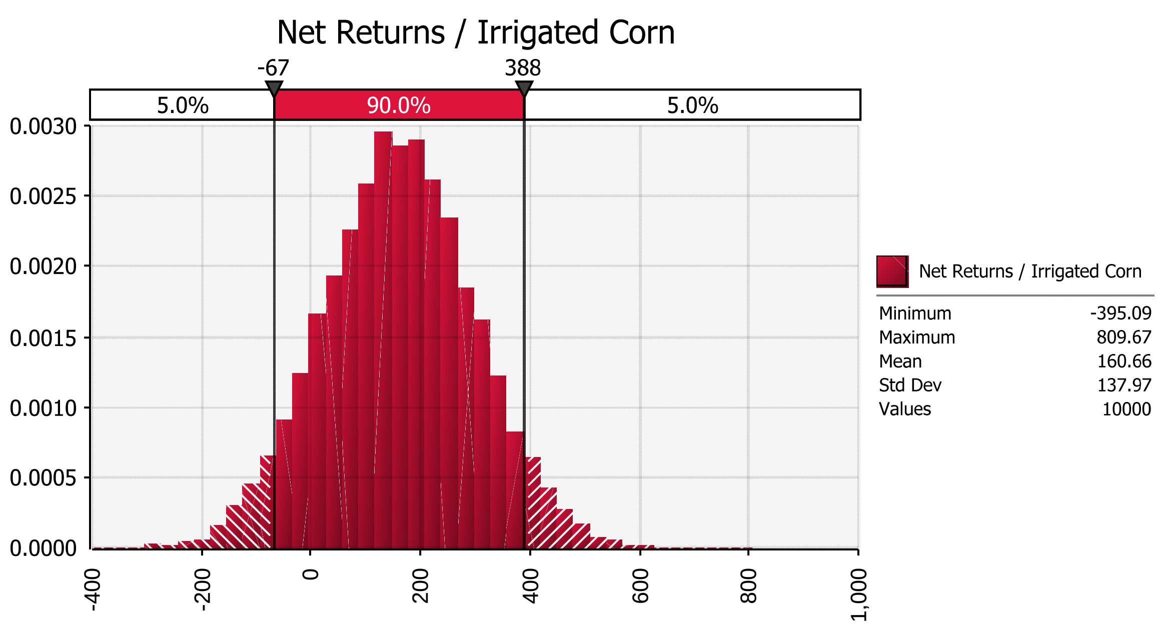

Yield / Irrigated Corn
114.3
228.2
5.0%
90.0%
5.0%
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
50
100
150
200
250
300
350
Yield / Irrigated Corn
Minimum 32.35
Maximum 333.54
Mean 171.29
Std Dev 34.49
Values 10000


Net Returns / HRS
-60
353
5.0%
90.0%
5.0%
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-400
-200
0
200
400
600
800
Net Returns / HRS
Minimum -360.89
Maximum 695.06
Mean 148.27
Std Dev 125.47
Values 10000

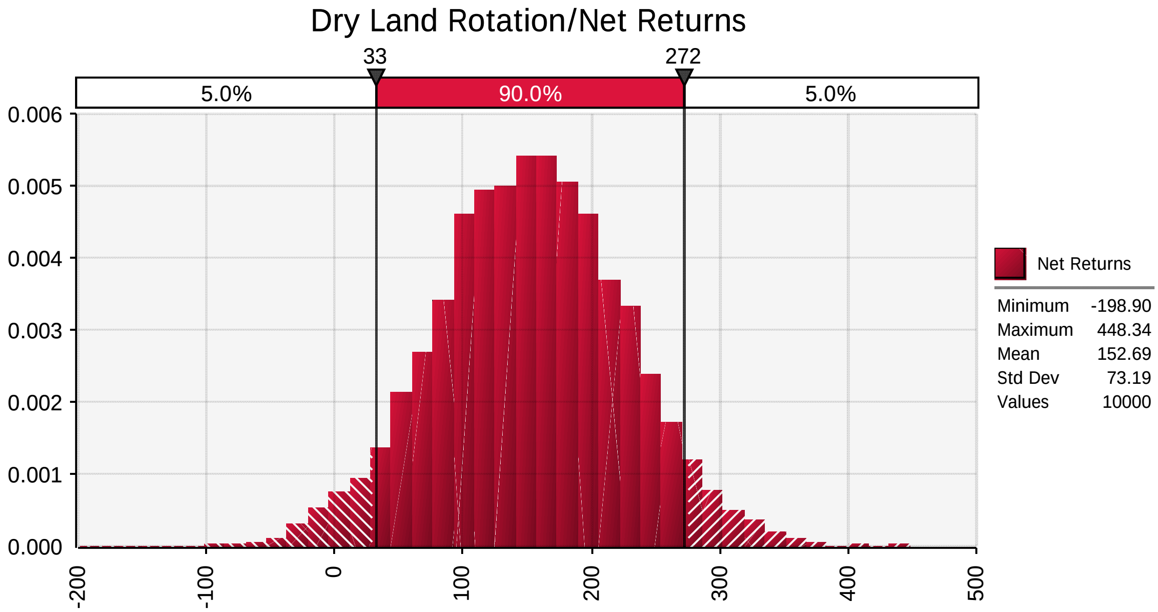

Net Returns / Canola
44
380
5.0%
90.0%
5.0%
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-200
-100
0
100
200
300
400
500
600
700
Net Returns / Canola
Minimum -162.28
Maximum 610.91
Mean 212.86
Std Dev 102.35
Values 10000



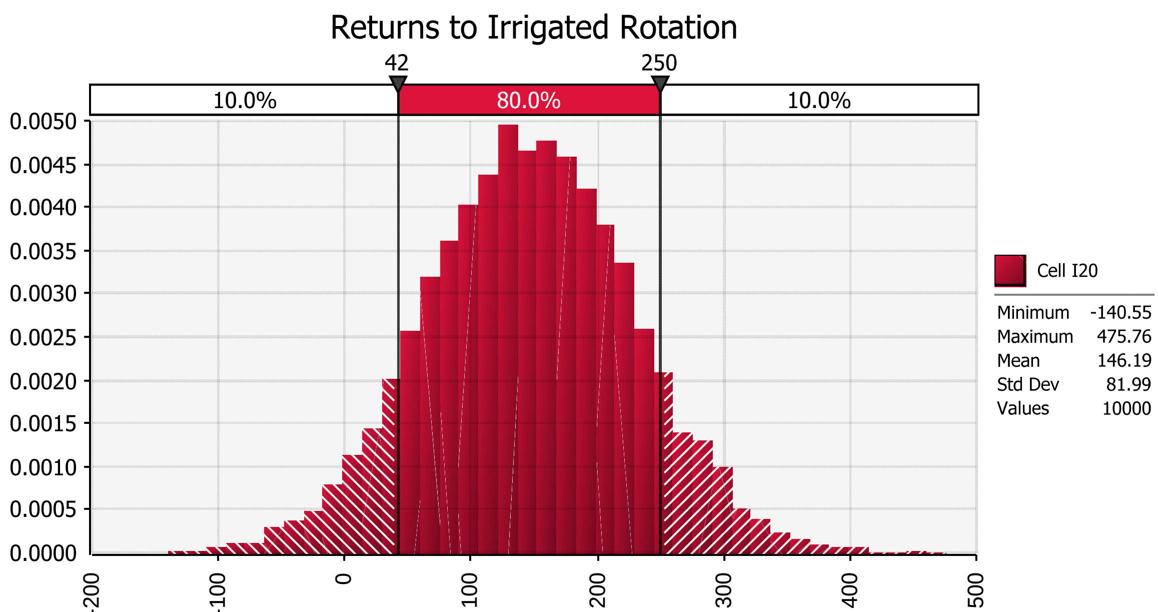
Net Returns / Soybean
-82
283
5.0%
90.0%
5.0%
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-400
-300
-200
-100
0
100
200
300
400
500
Net Returns / Soybean
Minimum -302.86
Maximum 486.22
Mean 101.36
Std Dev 110.89
Values 10000



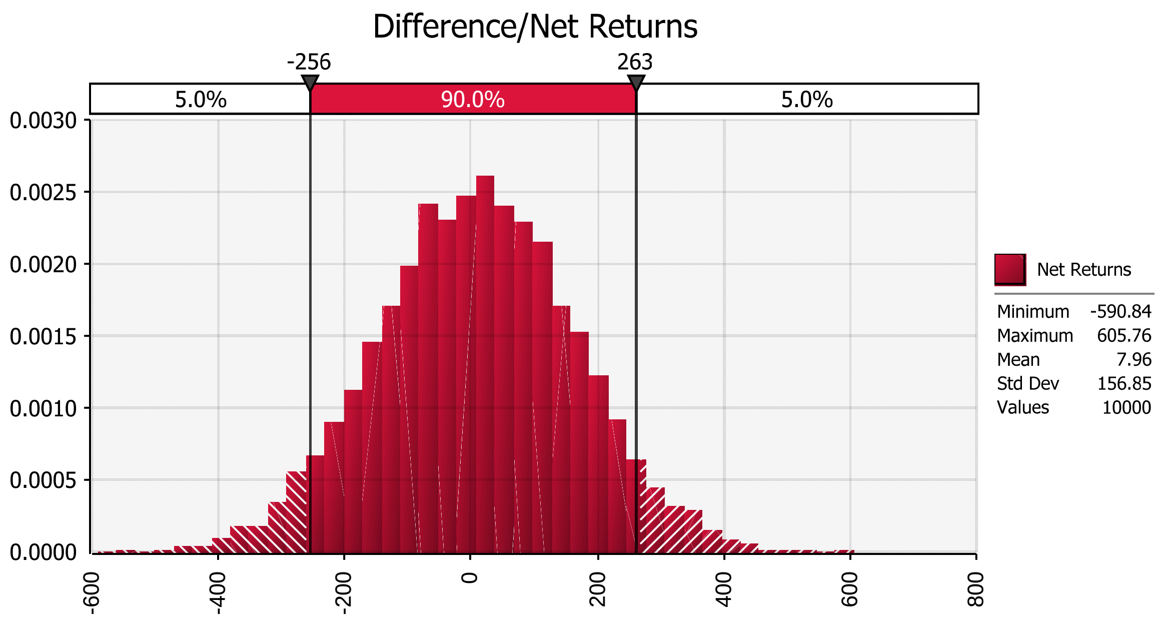
Net Returns / Irrigated Corn
-67
388
5.0%
90.0%
5.0%
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-400
-200
0
200
400
600
800
1,000
Net Returns / Irrigated Corn
Minimum -395.09
Maximum 809.67
Mean 160.66
Std Dev 137.97
Values 10000



Dry Land Rotation/Net Returns
33
272
5.0%
90.0%
5.0%
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-200
-100
0
100
200
300
400
500
Net Returns
Minimum -198.90
Maximum 448.34
Mean 152.69
Std Dev 73.19
Values 10000



Returns to Irrigated Rotation
42
250
10.0%
80.0%
10.0%
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-200
-100
0
100
200
300
400
500
Cell I20
Minimum -140.55
Maximum 475.76
Mean 146.19
Std Dev 81.99
Values 10000



Difference/Net Returns
-256
263
5.0%
90.0%
5.0%
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-600
-400
-200
0
200
400
600
800
Net Returns
Minimum -590.84
Maximum 605.76
Mean 7.96
Std Dev 156.85
Values 10000