Using a Computer Based Irrigation Decision Tool (WARAT) to Assess the Risk of Deficit Irrigation in Northwest Kansas

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Abstract

Irrigators facing reduced water allocations, either from declining water levels or policy mandates, are confronted with how to maximize profits and manage risk under reduced water allocations. A producer may elect to keep planting his existing crop mix at the reduced water level and accept lower yields, fully water fewer acres, or shift production to alternative crops. Decisions of this sort may well determine the producer’s future viability. Because of the complexity of those decisions he will most likely rely on computer based analytical tools to support the decision-making process.

This paper describes a Web-based decision tool (WARAT) that is being developed by a team of researchers at Kansas State University. The tool combines crop specific production and risk functions, crop production budgets, and weather data to identify combinations of crops mixes and water allocations that will come closest to meeting a producer’s profit goals. The tool will also provide a measure of the risk associated with each profit goal.

To illustrate how the tool might be used to help a producer determine crop mixes and water allocations for his profit and risk goals, we run simulations for an irrigated farm in Sheridan County, KS as we reduce the water allocation in 10% increments. The results of our simulations suggest that the profit maximizing level of water can be less than the amount of water required to obtain the highest yield, different crop-land-water combinations might give similar expected net returns but with different levels of variability, and that reasonably high returns can be achieved with significantly less water than that required for maximum yields.

I. Introduction

The increase in the number of acres of water-intensive crops in areas overlying the Ogallala Aquifer has policy makers and researchers looking at alternatives that achieve an absolute reduction in consumptive use of the aquifer's water. Producers are then faced with how to maximize profits and manage risk under reduced water allocation. Producers may elect to keep planting their existing crop mix and accept lower yields, or they may shift production to alternative crops. Decisions of this sort may well determine producers' future viability, so they will rely on available information and analytical tools to support their decision-making process.

There are several producer decision tools that address optimizing crop-land-water allocations, i.e., choosing those allocations that are the most profitable. The Crop Water Allocator was developed by researchers from Kansas State University (KSU-CWA) and is available as a downloadable compiled software program at http://www.oznet.ksu.edu/mil/cwa/. Researchers from the University of Nebraska at Lincoln developed the Water Optimizer (UNL-WO). UNL-WO is available as a downloadable Excel spreadsheet at http://real.unl.edu/h20/. Researchers from Colorado State University developed the Limited Irrigation Cropping Systems Analysis Tool (CSU-LICSA). CSU-LICSA is available as a downloadable Excel spreadsheet at http://limitedirrigation.agsci.colostate.edu/. In general, these products can be described as short-run optimization tools that yield the single crop-land-water combination which results in the maximum expected net return.

Producer decisions are often more complex than just determining what crop-land-water combination will give them the maximum expected net return. The variability of yields and prices create a level of 'risk' that is involved in obtaining that return. A producer decision tool that incorporates risk considerations into the decision making process will help a producer make choices that are best suited to his individual needs.

II. Background

In September 2006, the United States Department of Agriculture (USDA) Federal Crop Insurance Corporation (FCIC), through the Risk Management Agency (RMA) entered into a partnership with Kansas State University to develop the Water Allocation Risk Analysis Tool (WARAT). WARAT will be a Web-based risk analysis tool designed to help producers make informed cropping decisions under a variety of water use scenarios.

Producers often will accept a crop-land-water combination that generates a lower than maximum expected net return if the combination also generates less risk. In addition to analyzing a producer's expected net returns, analyzing the risk associated with diminished water supplies is a central function of WARAT. For the purpose of this project we define risk as the expected variation (standard deviation) in an individual producer's net returns over time. The variability in crop yield and crop price creates the variability in net returns.

Because crop yields and prices vary by production setting, and since producers vary in their attitudes toward risk, risk management cannot be viewed within a "one size fits all" recommendation. The WARAT is planned to benefit individual producers and will be developed to include distinctively localized information, provided (or chosen) by individual producers who will access the tool through the Internet.

III. Tool Overview

Theory of Operation

To assess the profitability and risk of various crop-land-water allocations, WARAT can be conceptualized as having three component parts: production functions, risk functions, and variable crop enterprise budgets. A production function is a mathematical relationship that relates the quantity of output produced to the quantity of inputs used in the production process. As an example, the production function for irrigated corn would quantify the relationship between the bushels of corn produced per acre to the acre-inches of irrigation water applied. Accurately predicting the shape of a production function is critical to the success of WARAT. Figure 1 illustrates a hypothetical production function for corn. This production function assumes normal or average rainfall. This production function indicates that in a year with average rainfall, if nine inches of irrigation water is applied then the expected yield is 187 bu/acre.

When coupled with a production function, a crop enterprise budget will allow a producer to choose the most profitable amount of irrigation water to apply to the crop. Of necessity, these crop enterprise budgets must vary with the expected crop yield. The crop enterprise budgets vary with yield because of the variable cost to apply irrigation water, variable fertilizer requirements, and variable harvest requirements. If a producer’s goal is to choose the water allocation that maximizes profits for a single crop on a fixed acreage, the optimization process is relatively simple. As the number of crops increase, the acreage allocation per crop is allowed to vary, and the water supply becomes limiting, then the computational requirements quickly exceed the producer's ability to manually calculate the optimal crop-land-water allocation.

Computer-based decision tools such as KSU-CWA, CSU-LICSA, and UNL-WO use optimization algorithms (such as Solver in Excel) to simplify the process. These tools assume that the producer has a single objective function, which is profit maximization. These tools essentially estimate all possible crop-land-water combinations and report the single crop-land-water allocation that produces the highest measure of net return.

The assumption that a producer has only one objective, which is maximizing profit, may be too simplistic to adequately mimic producer decisions in an environment where uncertain crop yields and prices induce risk associated with the expected profit. In particular, a producer’s decisions are best described as “trading off” risk and profit. Consequently, producers often will accept a crop-land-water combination that generates a lower than maximum expected net return if the combination also generates less risk. Put another way, when decisions are made in a risky environment, the manager cannot simply use expected prices and yields associated with a particular crop-land-water choice because the net return for each crop-land-water choice really is comprised of a distribution of returns as opposed to a single value. It is these probability distributions that help convey the magnitude of the risk involved.

To incorporate yield risk into the crop-land-water allocation decision, the notion of a risk function needs to be developed. Although we ultimately are interested in risk associated with net returns, it is helpful to first consider risk in a piecemeal fashion, where physical units are considered, not only dollars. In that context, a “risk” function can be conceptualized as a mathematical relationship that relates variability in the quantity of output produced to the quantity of inputs used in the production process. As an example, the risk function for irrigated corn would quantify the relationship between the variability in expected yield to the acre-inches of irrigation water applied. Accurately predicting the shape of a risk function is critical to the success of WARAT. Figure 2 illustrates a hypothetical risk function for corn. This risk function indicates that over time, if nine inches of irrigation water are applied, then the expected yield would be 187 bu/acre, but yield will vary with rainfall and other factors and the expected standard deviation of yield is 22.5 bu/acre.

At a given crop-water combination (how many inches of irrigation water are applied to an acre of a specific crop), the production function provides the expected yield, and the risk function provides the expected standard deviation of yield. Using a normal statistical distribution, these two values together define a probability distribution of the expected yield at a given gross irrigation application.

Given one possible crop-land-water *choice*, the distribution of the expected yield allows the net revenue to be simulated given crop price. To effect such simulations we use a Monte Carlo procedure, which essentially is a repetitive/iterative what-if game. A single iteration, referred to as a *possibility*, answers the question: What would the net return for the crop-land-water possibility have been if the yield had been equal to the simulated yield, where the simulated yield may be different from the expected yield? Practically speaking, a single possibility (iteration in our Monte Carlo procedure) represents a single year that is as likely to occur as any other possibility. The simulated yield is drawn from a probability distribution where the mean is defined by the production function and the standard deviation is defined by the risk function. Given a sufficiently large number of iterations (N), the mean of the simulated net revenue distribution will converge. Ignoring crop and input prices for now, the mean of the simulated distribution defines the expected net revenue of the possible crop-land-water choice, and the standard deviation of the simulated distribution defines the variability/risk of net revenue associated with the possible crop-land-water choice. Note that in this paper, we refer to “net revenue” and “profit” interchangeably. Net revenue is to be interpreted as cash income less cash costs or the returns available to land and management.

The simulation of one possible choice for the crop-land-water allocation provides measures of net revenue and risk associated with that choice. The notion of decision making in a risky environment implies choosing between multiple crop-land-water allocation choices. A portfolio analysis framework is used to compare possible crop-land-water choices. The many possible crop-land-water choices generate differing risks and expected net returns.

The concept of ‘efficiency’ is used to identify the most likely crop-land-water choices to be of interest to a producer. The efficiency rule is based on the assumption that if the expected net returns for choice A is greater than or equal to the expected net return of choice B, and the variability of net revenues for choice A is less than the variability for choice B, then choice A will be preferred to choice B. The crop-land-water combinations that meet the efficiency rule are referred to as the efficiency frontier. WARAT uses simulation modeling coupled with portfolio analysis to assist the producer in trading off profit and risk in the crop-land-water decisions he makes. Put another way, the producer can choose to minimize risk conditional upon some acceptable profit or else maximize profit conditional upon some acceptable risk.

Other Choice Criteria

While producers consider the need to trade off net revenue and risk when making their crop-land-water decision, those may not be the only factors considered. WARAT is designed as a short-run decision tool, but a producer's annual decision often reflects long-run requirements or implications. Crop rotation requirements are an example of this; corn might be the most profitable crop in a given year but rotational considerations might require a portion of acreage to be allocated to soybeans. A producer might also have crop preferences that may override both profitability and risk considerations, at least our stylized measures of profit and risk. As a result, WARAT allows a producer to place both maximum and minimum constraints on acre and water allocation choices.

VIII. Applying WARAT

To demonstrate how WARAT picks various profit/risk scenarios, we use a hypothetical center-pivot irrigated field in Sheridan County Kansas. Sheridan County, in Northwest Kansas, has about 77,500 irrigated acres with approximately 92 percent of those acres under center-pivots. Nearly 78 percent of the irrigated acres are in corn. Other principal crops grown in Sheridan County are wheat, alfalfa, sunflowers, grain sorghum, and soybeans.

To begin using WARAT the user needs to enter some basic information. These include: field size, irrigation system type, gross available water, irrigation efficiency, pumping cost per acre-inch, and the crop mix he wishes to analyze. For this demonstration the default yields and budgets are used. WARAT makes several assumptions: that no-till is the cultural practice used; and that the irrigation system is in good repair, well maintained, and managed to make the most efficient use of the available water (timing).

For the hypothetical field in Sheridan County Kansas we assume that 125 acres are irrigated with a center pivot which has an application efficiency of 90%. A typical well in the area has the capacity to deliver 115 acre-feet during the growing season at a cost of $7.50 per acre-inch. For illustrative purposes we consider a crop mix that could include any combination of corn, soybeans, sorghum, sunflowers, and wheat. The default yields and economic information for Sheridan County are displayed in Table 1.

WARAT output is displayed in three ways: In tabular form (Table 2) that displays the expected net revenue (ENR) and standard deviation (STD) of the five most profitable crop/water allocations for a give amount of available water; a scatter plot of the best (highest ENR) possible crop/water choices (Figure 3); and a scatter plot of the efficient mean-variance frontier (Figure 4).[1] WARAT also generates a graph of the cumulative distribution function (CDF) of the five most profitable choices (Figure 5). The CDF gives the probability of the ENR being less than some value.

[1] The crop/water allocations that make up the mean-variance frontier are not necessarily the same as those with the highest ENR.

We run, in turn, simulations that reduce water in 10 percent increments. Table 3 displays the top pick from each of the incremental simulations while Figure 6 gives a visual illustration of the expected net revenue ENR and STD as available water declines. WARAT determines that the highest ENR for the simulation for which 100 percent of the water is available is $40,846 with a STD of $19,761. This was obtained with a crop mix of 125 acres of soybeans only and applying 93 acre-feet of water, all on the 125 acres of soybeans. The 93 acre-feet is only 81 percent of the 115 acre-feet of water available.

The next option given, with 100 percent of the water allocation available, uses a crop mix of 25 (20%) acres corn and 100 (80%) acres soybeans and used 21.3 acre-feet of water for the corn and 74.4 acre-feet of water for the soybeans.[2] This is 19 percent and 65 percent, respectively, of the water used, but still only 83 percent of the total water available. This choice gives an ENR of $40,727 and a STD of $18,844. While having a somewhat lower ENR than Option 1, Option 2 also has lower variability. This can be attributed to fully watering the corn to obtain the maximum expected yield and spreading the risk by planting two crops. This option might be preferred over Option 2 by a more risk averse producer.

Option 3 calculates an ENR of $40,607 and a STD of $18,991. Fifty (40%) acres were planted to corn and 75 (60%) acres were planted to soybeans. The corn was nearly fully watered with 42.3 acre-feet and 55.8 acre-feet went to the soybeans. The total of 98.4 acre-feet is still only 85 percent 115 acre-feet of the water available. This suggests that the cost of pumping the last 15 percent of water is greater than the returns from the extra yield that might be gained. A tabular summary of these results is found in Table 2.

When reducing the initial available water to 70 percent (80.3 acre-feet), WARAT projects an ENR of $39,857 with a STD of $21,433. This is obtained by applying all of the 80.5 acre-feet of water on 125 acres of soybeans. The next option with 70 percent water calculates an ENR of $39,660 and a STD of $20,429. Just over 16 acre-feet of water were applied to 25 acres of corn with 64.3 acre-feet of water applied to 100 acres of soybeans. This used all of the available water of 80.3 acre-feet.

The third option with 70 percent water uses 50 acres of corn and 75 acres of soybeans to generate an ENR of $39,462 with a STD of $20,794. Forty percent of the available water (32.1 acre-feet) was applied to the corn with the balance of the 80.3 acre-feet going to the soybeans. This series of options illustrates that a fairly high ENR can be maintained with less water but the variability (STD) goes up, i.e., obtaining high profits comes with greater risk. A tabular summary of these results is found in Table 4.

Continuing to ratchet down the water, at 50 percent of the original water allocation of 115 acre-feet for our 125 acre field, WARAT calculates the highest ENR to be $34,525 with a STD of $22,720. All of the land (125 acres) is planted to soybeans and all of the reduced available water (57.4 acre-feet) is applied. Reducing water further to 30 percent of the original allocation of 115 acre-feet gives a top ENR of $25,938 with a STD of $15,454. For this simulation WARAT shifts

[2] 21.3 acre-feet of water applied to 25 acres is the equivalent of 11 acre-inches, which is the default gross water requirement for a fully watered yield.

the acreage to sunflowers, a less water intensive crop. Declines in yields from lower irrigation levels and switching to lower value crops result in lowering revenues. Variability, as measured by the STD, increases as water available for irrigation drops. Tables 5 and 6 summarize these results.

IX. Summary

By running simulations for a hypothetical center-pivot irrigated field in Sheridan County, Kansas, we have shown that within a risk framework, the crop/water mix that gives the highest ENR might not be the optimal choice. Other choices, while having a lower ENR, may have lower risk and therefore be more appealing to more risk averse producers. We also show that applying all the water that is available may not be the most profitable. In cases where the cost of pumping the last two or three inches of water exceeds the marginal gain in yield, acceptable profit levels can be maintained with less water.

Faced with declining water allocations, either mandated or from natural declining water tables, irrigators must make a complex decision as to what crop and water mix will help him meet his profit goals while maintaining an acceptable level of risk. Computer based decision tools such as WARAT help producers with making that decision by easily making the calculations and comparisons.

Tables

Table 1. Default Values Used by WARAT for Sheridan County Kansas.

Crop	Irrigated Yield[1]	Dryland Yield[1]	GIR[2]	Price	Variable Costs Irrigated	Variable Costs Dryland
Corn	213	69	11.0	$3.97	$432	$238
Soybeans	70	25	9.9	$8.34	$176	$135
Sorghum	158	55	8.6	$3.63	$262	$168
Sunflowers	25	11.5	7.7	$18.31	$179	$153
Wheat	77	37	8.8	$5.55	$167	$130

[1]Yields are in bu/acre except for sunflowers which are in cwt/acre
[2]Gross irrigation required for a fully watered crop.

Table 2. WARAT Output – Most Profitable Choices for 100% of Available Water Allocation.

Option1

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	125.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	93.0	0.0	0.0	0.0	93.0
Expected Yield	0.0	69.6	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$0	$40,846	$0	$0	$0	$40,846
Standard Deviation of ENR	$0	$19,761	$0	$0	$0	$19,761

Option 2

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	25.0	100.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	21.3	74.4	0.0	0.0	0.0	95.7
Expected Yield	212.2	69.6	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$8,050	$32,677	$0	$0	$0	$40,727
Standard Deviation of ENR	$4,992	$15,809	$0	$0	$0	$18,844

Option 3

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	50.0	75.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	42.6	55.8	0.0	0.0	0.0	98.4
Expected Yield	212.2	69.6	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$16,100	$24,508	$0	$0	$0	$40,607
Standard Deviation of ENR	$9,983	$11,857	$0	$0	$0	$18,991

Option 4

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	75.0	50.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	63.9	37.2	0.0	0.0	0.0	101.1
Expected Yield	212.2	69.6	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$24,149	$16,339	$0	$0	$0	$40,488
Standard Deviation of ENR	$14,975	$7,904	$0	$0	$0	$20,177

Option 5

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	25.0	100.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	21.3	68.9	0.0	0.0	0.0	90.2
Expected Yield	212.2	68.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$8,050	$32,395	$0	$0	$0	$40,445
Standard Deviation of ENR	$4,992	$16,596	$0	$0	$0	$19,547

Table 3. Highest Expected Net Revenue (ENR) for Each Water Allocation

% Full Allocation	Acre-in	ENR	CV	STD
100%	11.0*	$40,846	48.4%	$19,761
90%	9.9	$40,846	48.4%	$19,761
80%	8.8	$40,819	48.9%	$19,945
70%	7.7	$39,857	53.8%	$21,433
60%	6.6	$37,725	59.5%	$22,429
50%	5.5	$34,525	65.8%	$22,720
40%	4.4	$30,398	73.2%	$22,244
30%	3.3	$25,938	59.6%	$15,454
20%	2.2	$20,593	68.8%	$14,169
10%	1.1	$14,270	66.1%	$ 9,431
0	0	$ 7,914	119.1%	$ 9,428

*The tool algorithm uses the 'profit maximizing' level of water, which in this example is less than the maximum amount of water available.

Table 4. WARAT Output – Most Profitable Choices for 70% of Available Water Allocation.

Option1

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	125.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	80.3	0.0	0.0	0.0	80.3
Expected Yield	0.0	67.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$0	$39,857	$0	$0	$0	$39,857
Standard Deviation of ENR	$0	$21,433	$0	$0	$0	$21,433

Option 2

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	25.0	100.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	16.1	64.3	0.0	0.0	0.0	80.3
Expected Yield	200.0	67.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$7,774	$31,886	$0	$0	$0	$39,660
Standard Deviation of ENR	$5,727	$17,146	$0	$0	$0	$20,429

Option 3

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	50.0	75.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	32.1	48.2	0.0	0.0	0.0	80.3
Expected Yield	200.0	67.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$15,548	$23,914	$0	$0	$0	$39,462
Standard Deviation of ENR	$11,454	$12,860	$0	$0	$0	$20,794

Option 4

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	75.0	50.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	48.2	32.1	0.0	0.0	0.0	80.3
Expected Yield	200.0	67.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$23,321	$15,943	$0	$0	$0	$39,264
Standard Deviation of ENR	$17,181	$8,573	$0	$0	$0	$22,461

Option 5

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	100.0	25.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	64.3	16.1	0.0	0.0	0.0	80.3
Expected Yield	200.0	67.8	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$31,095	$7,971	$0	$0	$0	$39,067
Standard Deviation of ENR	$22,907	$4,287	$0	$0	$0	$25,173

Table 5. WARAT Output – Most Profitable Choices for 50% of Available Water Allocation.

Option 1

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	125.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	57.4	0.0	0.0	0.0	57.4
Expected Yield	0.0	61.1	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$0	$34,525	$0	$0	$0	$34,525
Standard Deviation of ENR	$0	$22,720	$0	$0	$0	$22,720

Option 2

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	100.0	0.0	25.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	45.9	0.0	11.5	0.0	57.4
Expected Yield	0.0	61.1	0.0	26.7	0.0	
Expected Net Revenue (ENR)	$0	$27,620	$0	$6,467	$0	$34,087
Standard Deviation of ENR	$0	$18,176	$0	$3,209	$0	$20,397

Option 3

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	25.0	100.0	0.0	0.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	11.5	45.9	0.0	0.0	0.0	57.4
Expected Yield	177.0	61.1	0.0	0.0	0.0	
Expected Net Revenue (ENR)	$6,442	$27,620	$0	$0	$0	$34,062
Standard Deviation of ENR	$5,821	$18,176	$0	$0	$0	$21,272

Option 4

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	75.0	0.0	50.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	34.4	0.0	23.0	0.0	57.4
Expected Yield	0.0	61.1	0.0	26.7	0.0	
Expected Net Revenue (ENR)	$0	$20,715	$0	$12,934	$0	$33,649
Standard Deviation of ENR	$0	$13,632	$0	$6,417	$0	$18,442

Option 5

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	25.0	75.0	0.0	25.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	11.5	34.4	0.0	11.5	0.0	57.4
Expected Yield	177.0	61.1	0.0	26.7	0.0	
Expected Net Revenue (ENR)	$6,442	$20,715	$0	$6,467	$0	$33,624
Standard Deviation of ENR	$5,821	$13,632	$0	$3,209	$0	$19,268

Table 6. WARAT Output – Most Profitable Choices for 30% of Available Water Allocation.

Option 1

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	0.0	0.0	125.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	0.0	0.0	34.4	0.0	34.4
Expected Yield	0.0	0.0	0.0	22.7	0.0	
Expected Net Revenue (ENR)	$0	$0	$0	$25,938	$0	$25,938
Standard Deviation of ENR	$0	$0	$0	$15,454	$0	$15,454

Option 2

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	25.0	0.0	100.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	6.9	0.0	27.5	0.0	34.4
Expected Yield	0.0	49.9	0.0	22.7	0.0	
Expected Net Revenue (ENR)	$0	$5,084	$0	$20,751	$0	$25,835
Standard Deviation of ENR	$0	$4,184	$0	$12,363	$0	$15,394

Option 3

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	50.0	0.0	75.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	13.8	0.0	20.7	0.0	34.4
Expected Yield	0.0	49.9	0.0	22.7	0.0	
Expected Net Revenue (ENR)	$0	$10,169	$0	$15,563	$0	$25,732
Standard Deviation of ENR	$0	$8,368	$0	$9,272	$0	$15,998

Option 4

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	75.0	0.0	50.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	20.7	0.0	13.8	0.0	34.4
Expected Yield	0.0	49.9	0.0	22.7	0.0	
Expected Net Revenue (ENR)	$0	$15,253	$0	$10,375	$0	$25,628
Standard Deviation of ENR	$0	$12,552	$0	$6,181	$0	$17,196

Option 5

Crop	Crop 1 Corn	Crop 2 Soybeans	Crop 3 Sorghum	Crop 4 Sunflowers	Crop 5 Winter Wheat	Total
Acreage Allocation (acres)	0.0	100.0	0.0	25.0	0.0	125.0
Water Allocation (Gross Ac-Ft)	0.0	27.5	0.0	6.9	0.0	34.4
Expected Yield	0.0	49.9	0.0	22.7	0.0	
Expected Net Revenue (ENR)	$0	$20,337	$0	$5,188	$0	$25,525
Standard Deviation of ENR	$0	$16,735	$0	$3,091	$0	$18,875

Figures

Figure 1. Hypothetical Production Function for Corn

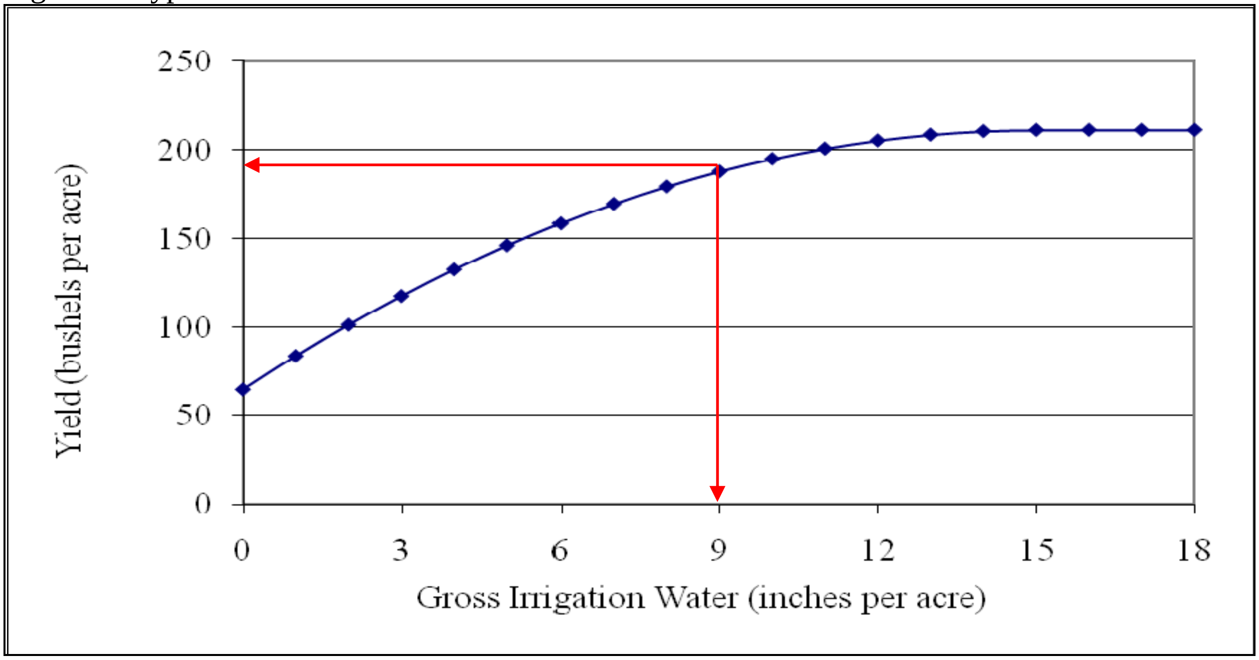


Figure 2. Hypothetical Production & Risk Function for Corn

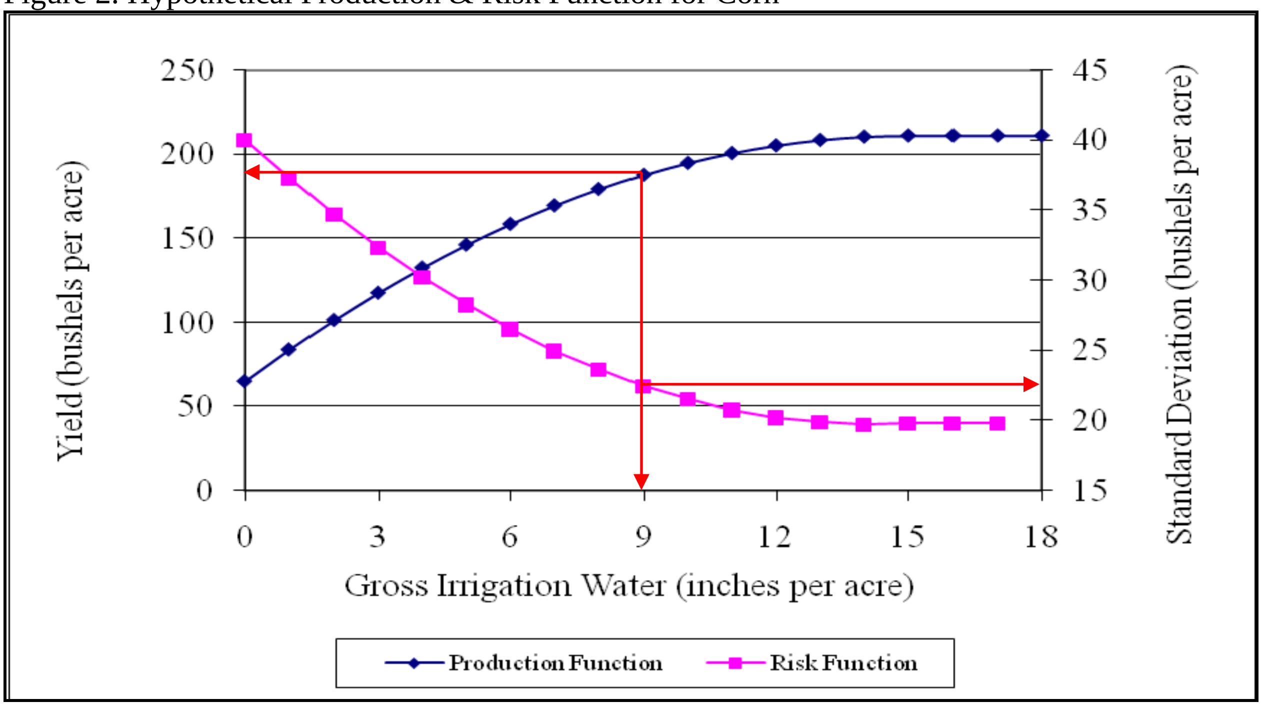


Figure 3. WARAT Output – Risk Profit Relationship for Multiple Choices

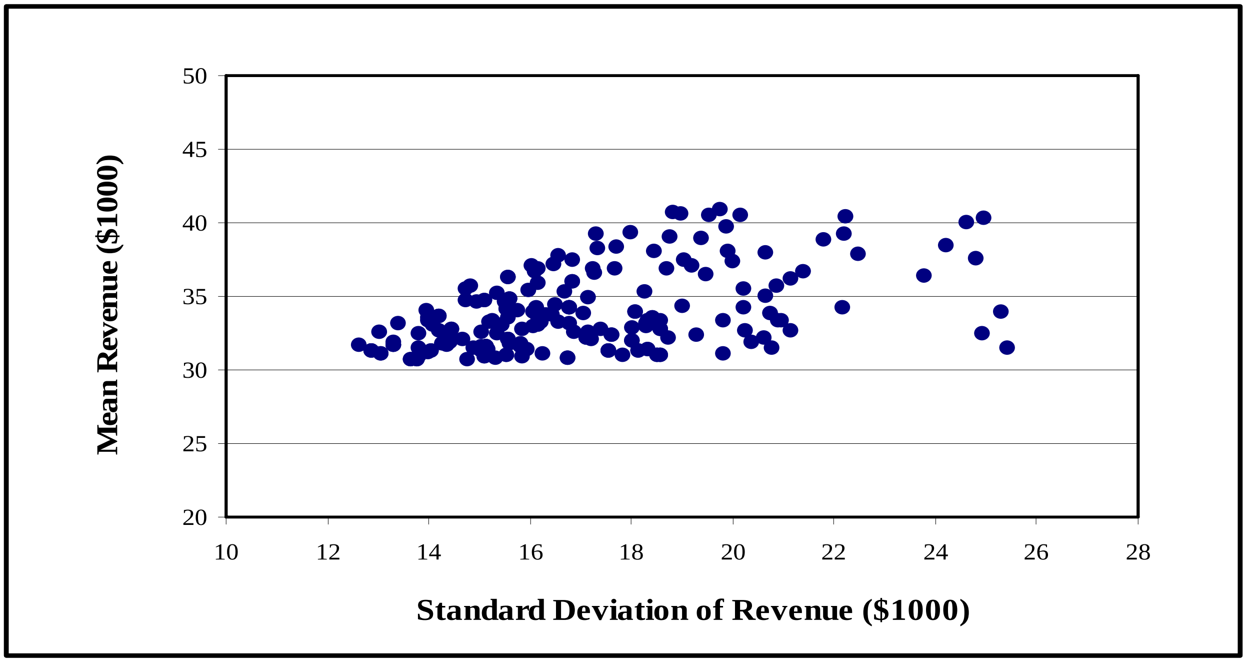


Figure 4. WARAT Output – Choices on the Efficient Mean Variance Frontier

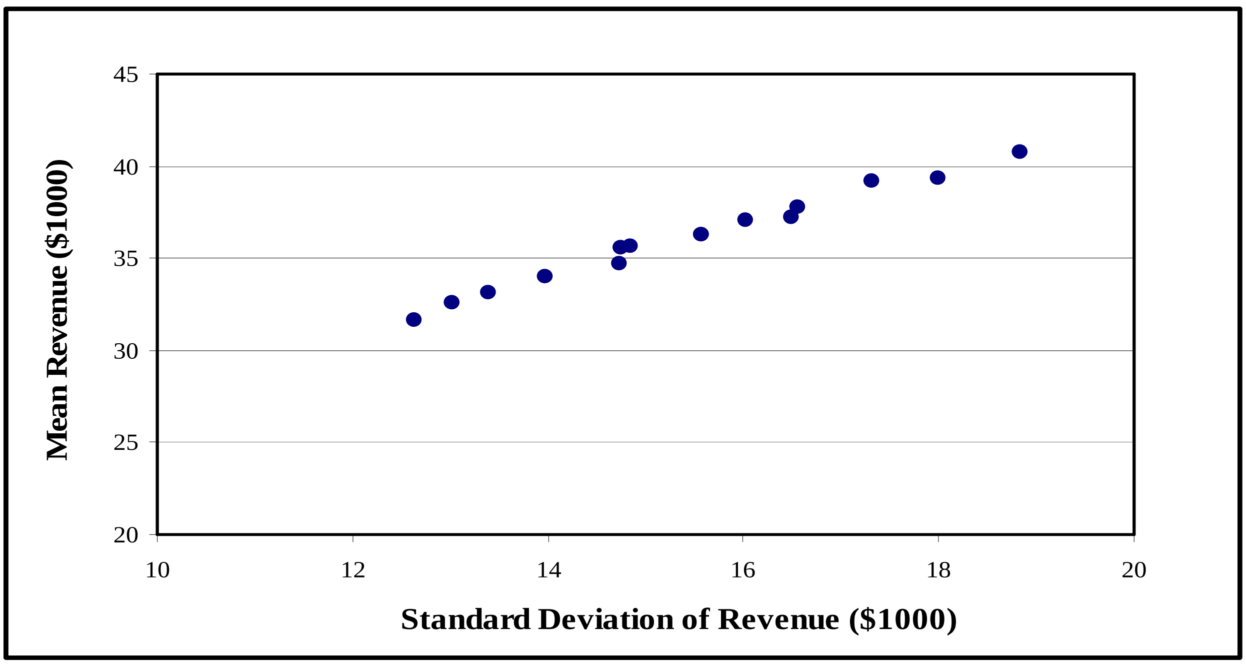


Figure 5. WARAT Output – Cumulative Distribution Functions for Five Best (most profitable) Choices

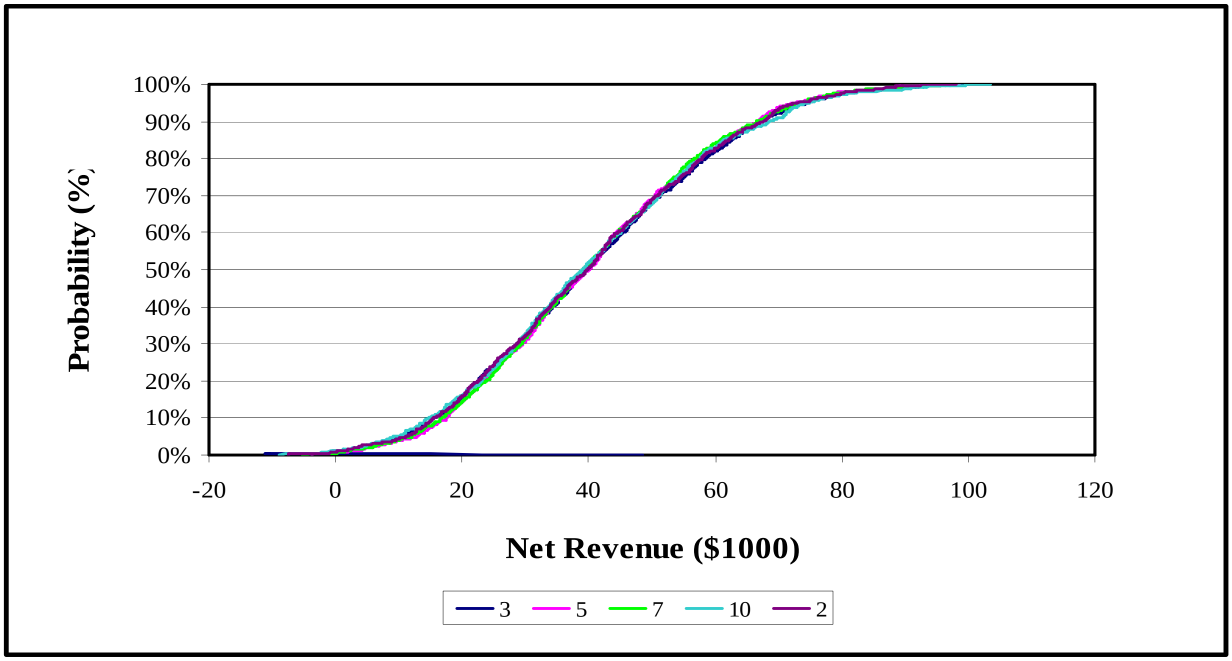
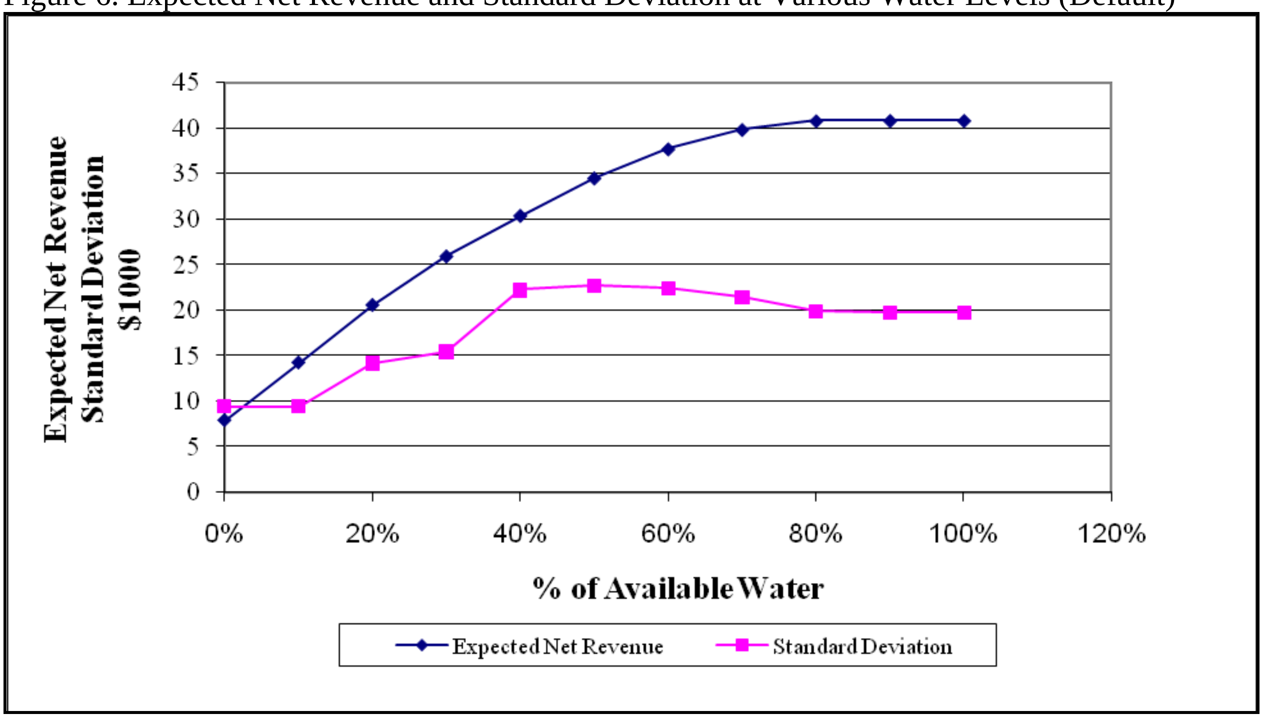


Figure 6. Expected Net Revenue and Standard Deviation at Various Water Levels (Default)



2008 R&P WARAT Producer Survey

Please take a few minutes to complete this survey. Your input will help assure that our research is focused on those areas that will be most useful to producers. Please leave your completed survey for us to collect. Thank you.

1) Are you an irrigator? Yes____________ No_____________

2) If you are not an irrigator what is your primary business?

Finance_______ Research/Extension________ Farm Manager________ Government_________

3) If you are an irrigator, what is your primary system type?

Flood_________ Pivot________ Drip________ Other________ (specify)

4) What is your primary energy source?

Diesel_________ Natural Gas_______ Propane_______ Electricity_________

5) Do you now or will you in the near future (next 5 yrs) face reduced water allocations?

Yes_________ No_________

7) If you are facing reduced water allocations will this come from:

Mandates________ or declining water levels________?

8) Should ground water usage be controlled by government?

Yes_________ No_________

9) Would you use a Web-based decision tool such as WARAT to help you make crop/water allocation decisions?

Yes_________ No_________

10) Should the users of such a decision tool be able to input their own economic and yield information?

Yes_________ No_________

11) If a decision tool such as WARAT indicates that you could maintain relatively high revenue but with higher risk by using deficit irrigation how likely would you be to follow that recommendation?

Very likely_______ Somewhat Likely_______ Not very likely_______ Don't Know_______

12) Do you use other computer based decision tools for irrigation management?

Yes_________ No__________ If yes, which one(s)?________________________________

13) Which of the following forms of risk affects your farming business the most?

Yield________ Commodity Prices_______ Input Prices_______ Weather_______

14) Rate your interest in obtaining additional information on deficit irrigation or computer decision tools:

Very Interested_______ Somewhat Interested______ Not at all interested _______