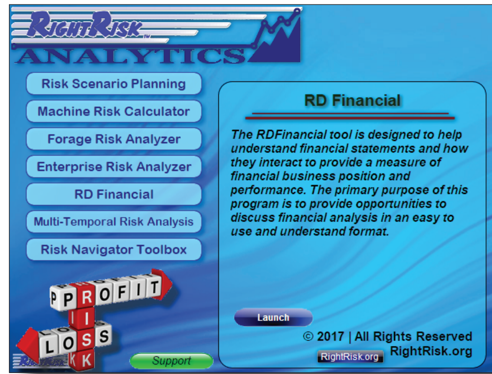
Every Drop Counts: Allocating Scarce Irrigation Water

Ted Baker* is a Wyoming crop and hay producer who faces a common challenge among irrigated farmers in the region: a limited water supply for irrigation. Midway through the growing season, Ted had been following his usual irrigation schedule when a water-limiting event occurred. He believes he has three realistic options: focus irrigation on the alfalfa, focus on the corn, or split the water between both crops; the latter would likely lead to inadequate irrigation for each. Since the third option seems unfeasible, he has ruled it out. To support his decision-making, Ted plans to use a partial budgeting framework, along with the *Risk Scenario Planning* tool from RightRisk.org.



His Actual Production History (APH) yield for corn is 180 bushels per acre, and he anticipates receiving $3.75 per bushel at harvest, Table 1. With sufficient water, he anticipated meeting or even exceeding his average yield. However, without adequate irrigation, the corn will rely entirely on rainfall, leading to potential yields ranging from 10 to 100 bushels per acre, with the most likely outcome being around 75 bushels per acre. Meanwhile, the alfalfa has already been irrigated once, producing 1.5 tons per acre so far. Reaching its full potential of an additional 2.5 to 3.5 tons per acre would require more irrigation. Without further water, Ted estimates that the alfalfa will produce only 1 additional ton at most for a total of 2.5 tons per acre.

RightRisk Analytics
Tools and guides are available at no cost at the website https://RightRisk.org

Risk Scenario Planning

One basic approach to evaluating risk management alternatives is through a cost-benefit analysis using a partial budget framework. This method assesses the potential impact on net income or net benefit from a proposed change in a business or enterprise. Examples of such management changes include expansion, purchasing machinery or equipment, altering a crop rotation, modifying marketing strategies, or—as in this case—deciding how to allocate limited resources for the best return.

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A partial budget categorizes potential decisions into four areas: added returns, reduced costs, added costs, and reduced returns. The net effect of the proposed change or decision is calculated by summing the potential benefits (added returns and reduced costs) and subtracting the potential costs (added costs and reduced returns), Figure 1.

The main challenge with partial budgets is that the numbers used are often just estimates. Many of the values, such as yields, prices, or costs, are imperfect guesses and do not account for the inherent risk. The problem arises when decisions are made based on these broad assumptions, without considering the variability in potential outcomes.

Table 1. Corn and Alfalfa Potential Yields and Prices

	Expected Yield	Expected Price	Price Range
Scenario #1 - Water Corn			
Corn	180 bu/ac	$3.75/bu	$3.40-$4.10/bu
Alfalfa	2.5 ton/ac	$100/ton	$90-$145/ton
Scenario #2 - Water Alfalfa			
Corn	75 bu/ac	$3.75/bu	$3.40-$4.10/bu
Alfalfa	4.5 ton/ac	$100/ton	$90-$145/ton

In Ted's case, the objective is to gather information that will help him identify which crop would be the most profitable to irrigate with his remaining limited water supply. This prompts several key questions: What price and yield assumptions should be made for each crop? How might changes in prices and yields impact his decision and the resulting budgets? Lastly, what is the likelihood that Ted's choice will result in a positive net return?

Figure 1. Partial Budget Framework

Risk Scenario Planning tool

The *Risk Scenario Planning* (RSP) tool is a partial budgeting tool designed to address the best guess problem. Like a typical partial budget, it includes sections for added and reduced costs and returns. What sets the RSP tool apart is its analysis section, which allows users to incorporate risk using one or two uncertain variables in their estimates. This feature enables users to input a range of forecast values—minimum, maximum, and most likely values—for the uncertain variables, generating a probability distribution that illustrates the breadth of potential outcomes. Based on the variables entered, the RSP tool produces estimates of the net benefit, along with the associated probabilities.

RSP Tool Input

The input for the RSP tool follows a partial budget format and includes all the items Ted expects to change from this point forward, for the moment ignoring the 1.5 tons of hay already harvested. In his first analysis, Ted assumes he will use all of his limited water on the corn acres, with all entries input on a per-acre basis. Under Added Returns, Ted inputs the expected corn yield with sufficient irrigation, estimated at 180 bushels per acre, along with an expected price of $3.75 per bushel, Figure 2. He also enters the expected 1 additional ton of alfalfa and price of $100 per ton. For Reduced Costs, he includes savings from harvesting 2 fewer tons of alfalfa per acre than anticipated with full irrigation. These costs include cutting, raking, baling, and retrieving bales, totaling $100 per acre, Figure 3. The combined positive effects are estimated at $875 per acre.

For the negative effects, Ted enters the cost to harvest corn at $0.30 per bushel for 180 bushels under Added Costs, Figure 4. He also enters the costs for cutting, raking, baling, and retrieving bales for the 1 additional ton of alfalfa he expects to harvest, totaling $50 per acre. Under Reduced Returns, he accounts for the reduced hay yield, entering 2 tons per acre at $100 per ton with no further irrigation, Figure 5. The combined negative effects are estimated at $304 per acre. Using the simple budget format—added returns and reduced costs minus added costs and reduced returns—the total net benefit of this scenario is calculated to be $571 per acre, Figure 6.

Figure 2. Added Returns

Added Returns	Quantity	Value	Total
Corn (irrigated, bu/acre)	180	$ 3.75	$ 675.00
			$ -
Alfala (non-irrigated, tons/acre)	1	$ 100.00	$ 100.00

Figure 3. Reduced Costs

Reduced Costs	Quantity	Value	
Cut hay (tons/acre)	2	$ 15.00	$ 30.00
Rake and bale hay (tons/acre)	2	$ 25.00	$ 50.00
Retrieve bales (tons/acre)	2	$ 10.00	$ 20.00
			$ -

Figure 4. Added Costs

Added Costs	Quantity	Value	
Harvest irrigated corn ($/bushel)	180	$ 0.30	$ 54.00
			$ -
Cut non-irrigated hay (tons/acre)	1	$ 15.00	$ 15.00
Rake and bale non-irrigated hay (tons/acre)	1	$ 25.00	$ 25.00
Retrieve non-irrigated hay bales (tons/acre)	1	$ 10.00	$ 10.00

Taking Risk Into Account

One powerful feature of the RSP tool is its ability to account for variability in two key factors of the partial budget. Would

Figure 5. Reduced Returns

Alfalfa hay (tons/acre)	2	$ 100.00	$ 200.00
			$ -
			$ -

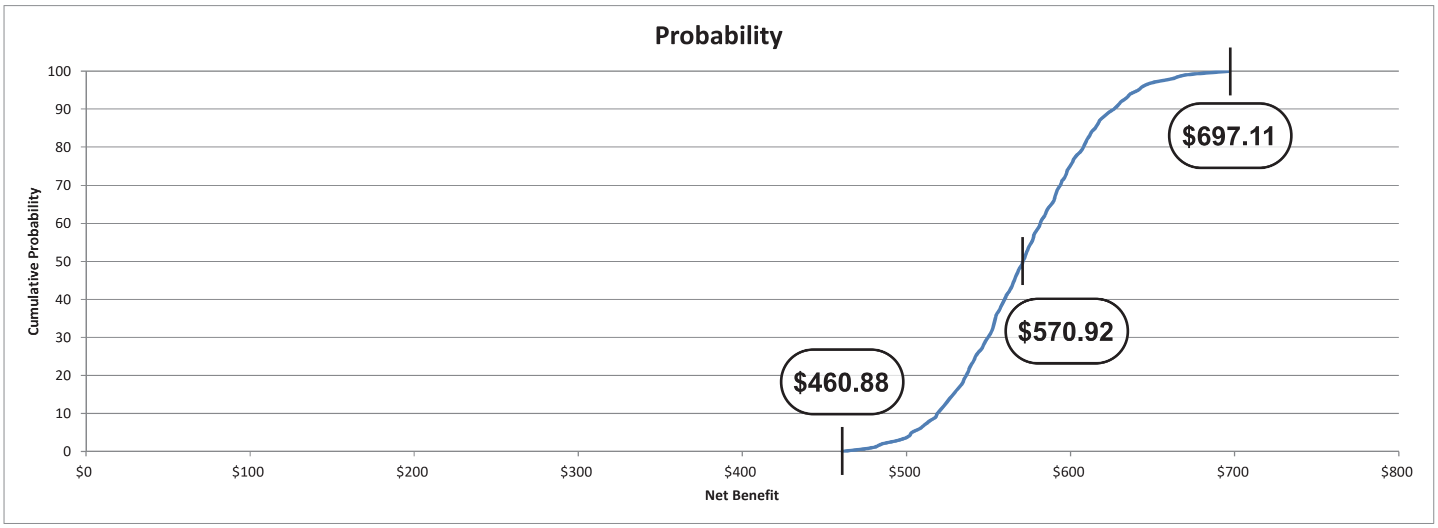
Figure 6. Total Net Benefit of Watering Corn / No Alfalfa

Total Positive Effects			Total Negative Effects		
(Added Returns + Reduced Costs)	$	875.00	(Added Costs + Reduced Returns)	$	304.00
			Net Benefit of: Water Corn / No Alfalfa	$	571.00

Figure 7. RSP Tool Risk Inputs

Uncertain Value 1		☑ Include	Uncertain Value 2		☑ Include
Description	Cell		Description	Cell	
Corn price	D7		*Corn yield*	C7	
Current Value (Most Likely)	3.75		Current Value (Most Likely)	180	
Minimum Value	3.4		Minimum Value	150	
Maximum Value	4.1		Maximum Value	210	

Figure 8. RSP Tool Probability Curve, Water Corn / No Alfalfa and Variable Corn Price and Yield



Ted's decision change if the corn yield dropped to 150 bushels per acre or if the price fell to $3.40 per bushel? These values can be entered into the Risk Scenario section of the RSP tool.

For the first uncertain variable, Ted inputs the corn price with a most likely value of $3.75 per bushel, a minimum of $3.40, and a maximum of $4.10, Figure 7. For the second uncertain variable, he enters the corn yield with a most likely value of 180 bushels per acre, a minimum of 150, and a maximum of 210. Finally, he modifies the formula in the cell for corn yield under Added Costs to reference the corn yield entered in cell C7 (=C7). This way, when the RSP tool updates yield estimates in cell C7, it will also adjust the added cost estimate for harvesting corn accordingly.

Clicking RUN prompts the tool to evaluate over 1,000 alternative scenarios, generating a probability curve that shows the cumulative probability of potential net benefits based on the inputs provided, Figure 8. The curve illustrates the upper and lower bounds of the potential net benefit from irrigating corn instead of alfalfa. According to this analysis, there is a 0 percent chance of realizing a net benefit below $460.88 per acre and a 100 percent chance that the net benefit will not exceed $697.11 per acre. The most likely outcome, with a 50/50 probability, is a net benefit of $570.92 per acre.

Additional considerations

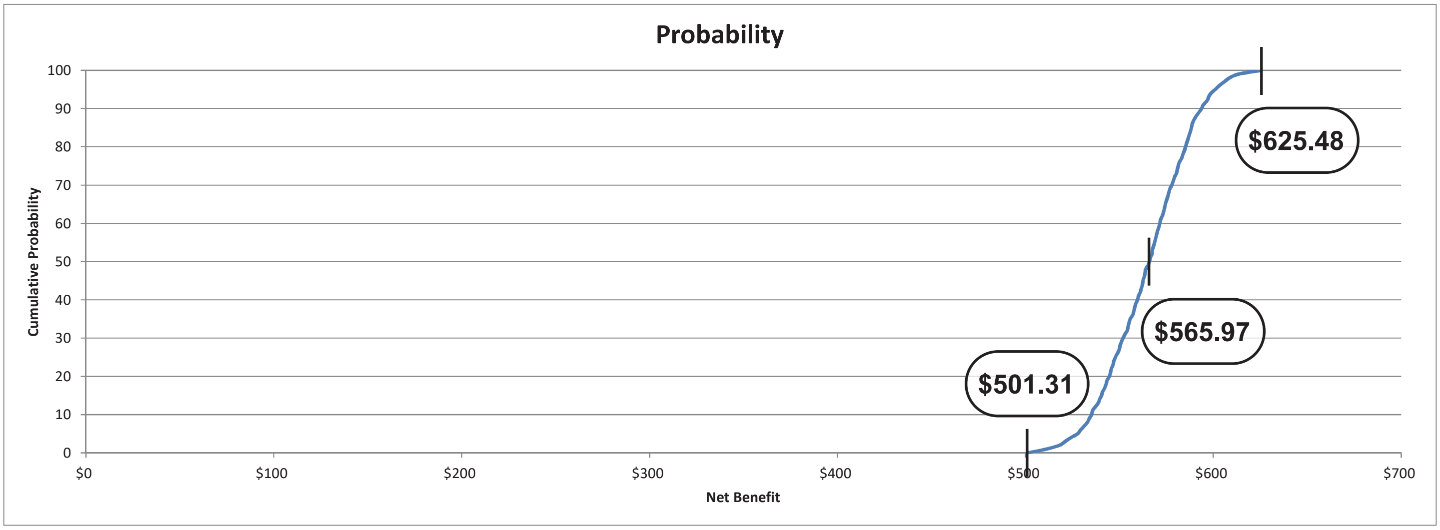
Ted is also concerned about the fluctuating prices of corn and alfalfa, which could influence his decision. He can address these uncertainties in the RSP analysis by setting the corn price with a most likely value of $3.75 per bushel, a minimum of $3.40, and a maximum of $4.10 and hay price at a most likely value of $100 per ton, a minimum of $90 and a maximum of $145 per ton, Figure 9. To ensure accuracy, Ted adjusts the formula in the cell for hay price under Reduced Returns to reference the alfalfa price entered in cell D9 (=D9). This way, when the RSP tool updates yield estimates in D9, it will automatically adjust the reduced returns estimates accordingly.

Clicking RUN again prompts the RSP tool to evaluate over 1,000 alternative scenarios, generating a probability curve similar to the first result with a few notable differences, Figure 10. The most likely or 50/50 outcome is $565.97, with a minimum of $501.31 and the maximum expected at $625.48. The results outlined by the two probability distributions show that the variability

Figure 9. RSP Tool Risk Inputs, Variable Alfalfa Price and Yield

Risk Scenarios					
Uncertain Value 1		☑ Include	**Uncertain Value 2**		☑ Include
Description	**Cell**		**Description**	**Cell**	
Corn price	D7		*Alfalfa price*	D9	
Current Value (Most Likely)	3.75		Current Value (Most Likely)	100	
Minimum Value	3.4		Minimum Value	90	
Maximum Value	4.1		Maximum Value	145	

Figure 10. RSP Tool Probability Curve, Water Corn / No Alfalfa and Variable Alfalfa Price and Yield



associated with corn and alfalfa prices is less of a factor influencing total net benefit than the variability associated with corn price and yield found under the first run of the RSP tool. This is demonstrated by the tighter distribution, or more limited range between the minimum and maximum, resulting from variable alfalfa prices and yields.

Results and Further Analysis

Ted Baker can reasonably conclude from this analysis that, based on his current assumptions and accounting for some of the price and yield risks associated with corn and alfalfa, applying the available irrigation water to corn rather than alfalfa will result in a net benefit of $566 per acre. To further explore his options, Ted may want to assess the outcomes of irrigating alfalfa instead of corn, or consider the less promising scenario of splitting the limited water between both crops.

However, as Ted evaluates his options, he should also account for the assumption that there will be no other significant production setbacks, such as hail or adverse weather conditions, which could substantially reduce corn yields below expectations. Additionally, Ted should consider additional forms of risk protection, such as crop insurance, to safeguard against potential losses during unfavorable years.

Further analysis could help in evaluating Ted Baker's management options under a limited irrigation water supply. Several variables in the partial budget were assumed to remain constant, even though they likely contain some uncertainty that could impact the final decision. This limitation points out one of the constraints of the RSP tool; it is only able to evaluate two variables in any given budget. The Applied Risk Analytics bulletin, *Managing Limited Irrigation Water: Identifying the Best Available Option*, delves deeper into evaluating Ted's options using the *Multi-Temporal Risk Analyzer* (MTRA) tool. The MTRA tool allows users to account for uncertainty in each variable of the analysis and to assess alternative approaches over multi-year periods.

Visit RightRisk.org to access the RightRisk risk analytics toolbox, including the *Risk Scenario Planning* tool, the *Multi-Temporal Risk Analyzer*, and several other risk decision aids. As a premier risk management education site, RightRisk.org also offers numerous presentations, courses, and resources designed to assist producers at any level of risk management expertise.

** The Baker operation is a case study example created to demonstrate RightRisk tools and their applications. No identification with actual persons living or deceased, places, or agricultural operation is intended nor should be inferred.*