Applied Risk Analytics

Managing Limited Irrigation Water: Identifying the Best Available Option

Midway through the previous growing season, a water-limiting event disrupted the usual irrigation cycle for many farmers in the area. Local crop and hay producers faced the challenge of an unexpectedly limited water supply for irrigation. Ted Baker* believed he had only 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. The Applied Risk Analytics bulletin, *Every Drop Counts: Allocating Scarce Irrigation Water*, explores Ted's options in greater detail using the *Risk Scenario Planning* (RSP) tool from RightRisk.org.

Early in the current crop season, it has become clear that the water shortage may extend for one or two additional years. Here, Ted's available choices will be carefully evaluated using a partial budgeting approach with the *Multi-Temporal Risk Analyzer* (MTRA) tool.

Limited Water Options

Ted's assumptions for what yields would look like if either one or the other crop is irrigated are summarized in Table 1, along with the expected price range for both crops. Ted's previous analysis suggested that irrigating the corn and living with the reduced alfalfa yield could result in a positive outcome; a net benefit of around $566/ac by following this strategy. The limitations of the RSP analysis lie in the fact that Ted could not address all of the uncertainty in each of the budget factors together.

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

Cost Benefit Analysis via Partial Budgets

A classic 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 classifies potential decisions into four main categories: added returns, reduced costs, reduced returns, and added costs. 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 (reduced returns and added costs), Figure 1.

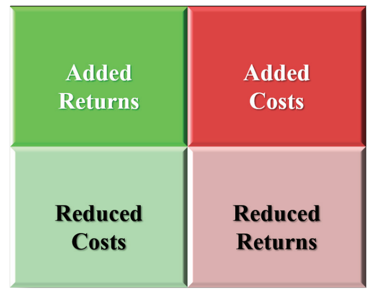
One of the main challenges with partial budgets is that the figures used are often just estimates. Many values, such as yields, prices, or costs, are based on imperfect guesses and do not account for inherent risks. Problems can arise when decisions are made based on these broad assumptions without considering 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 goal is to provide information that will help him determine which crop will be the most profitable to irrigate with a limited water supply, potentially over the next couple of years. This represents a more complex budgeting scenario, with multiple factors likely to vary over time on both the cost and return sides. Accounting for the time value of money also becomes a critical consideration. Even over a one-year period, it is essential to factor in the interest rate or opportunity cost and its influence on budget outcomes.

Figure 1. Partial Budget Framework



Multi-Temporal Risk Analyzer Tool

The *Multi-Temporal Risk Analyzer* is a risk analytics tool designed to provide users with a long-term perspective on the uncertainty associated with proposed business changes. It follows a partial budget framework and allows users to incorporate expected changes for up to 20 years into the future, offering a comprehensive view of long-term budget expectations.

While similar to the RSP tool, MTRA allows users to incorporate risk for any of the potential inflows or outflows by entering maximum, minimum, and most likely values. This feature provides a more detailed analysis of the budget, using a range of potential values to account for inherent uncertainty in the process. Another unique feature of MTRA is the ability to designate which years each budgeted factor is expected to influence over the 20-year period. This enables users to assess the effects of specific variables on the potential net benefit. In addition, MTRA accounts for the time value of money by applying the interest rate entered, allowing for both cash and present value analysis.

MTRA Tool Input

To assess Ted's decision to irrigate corn instead of alfalfa, we begin by entering the data for yields, prices, and costs into the MTRA partial budget. Using Ted's assumptions for maximum, minimum, and most likely yields and prices, as outlined in Table 1, he calculates an estimated range of values per acre for each relevant section of the MTRA tool.

Under Added Returns, he inputs the corn crop data. He estimates the minimum return by assuming a yield of 150 bu/ac at $3.40/bu, resulting in $510/ac. The most likely return is calculated based on a yield of 180 bu/ac at $3.75/bu, totaling $675/ac. The maximum return is estimated at $861/ac, assuming a yield of 210 bu/ac at $4.10/bu, Figure 2. Ted also enters the return for an expected 1 additional ton of non-irrigated alfalfa valued at $100 per ton with a range from $50 (0.5 tons/ac) to $150 (1.5 tons/ac). In the Reduced Costs section, Ted lists the costs associated with not harvesting the reduced tonnage of alfalfa. He estimates that the alfalfa yield will be reduced by at least 1.5 ton/ac, at most 2.5 tons/ac, and most likely 2 tons/ac. Cutting alfalfa is expected to cost $30/ac, with a range of $20 to $40/ac. Raking and baling costs will range from $38 to $63/ac, with a most likely value of $50/ac. Retrieving bales is estimated to cost between $15 and $25/ac, with a most likely value of $20/ac, Figure 3.

The Added Costs cover harvesting the corn and hay. This includes combining, hauling, and other related costs for the corn, as well as cutting, raking, baling, and retrieving bales for the hay. The most likely corn harvesting cost is $54/ac,

Figure 2. Added Returns

Added Returns				
Corn (irrigated, $/acre)	$ 675	$ 510	Low
		$ 861	High
Alfalfa hay (non-irrigated, $/acre)	$ 100	$ 50	Low
		$ 150	High

Figure 3. Reduced Costs

Reduced Costs			
Cut hay ($/acre)	$ 60	$ 45	Low
		$ 75	High
Rake and bale hay ($/acre)	$ 50	$ 38	Low
		$ 63	High
Retrieve bales ($/acre)	$ 20	$ 15	Low
		$ 25	High

Figure 4. Added Costs

Added Costs			
Harvest corn ($/acre)	$ 54	$ 45	Low
		$ 63	High
Cut non-irrigated hay ($/acre)	$ 15	$ 8	Low
		$ 23	High
Rake and bale non-irrigated hay ($/acre)	$ 25	$ 13	Low
		$ 38	High
Retrieve non-irrigated bales ($/acre)	$ 10	$ 5	Low
		$ 15	High

Figure 5. Reduced Returns

Reduced Returns			
Alfalfa hay ($/acre)	$ 200	$ 180	Low
		$ 290	High

Figure 6. MTRA Single Draw Results Table

Interest Rate: 0.00%

	CASH-basis analysis				
YEAR	*Projected* Total Added Returns	*Projected* Total Reduced Costs	*Projected* Total Added Costs	*Projected* Total Reduced Returns	*Projected* NET ANNUAL Return
1	782	133	108	209	598
19	-	-	-	-	0
20	-	-	-	-	0

Net Return:	**598**
MIN Rtn:	0
AVG. Rtn:	30
MAX Rtn:	598

Interest Rate: 10.00%

	PRESENT VALUE-basis analysis				
YEAR	*Projected* PV-Total Added Returns	*Projected* PV-Total Reduced Costs	*Projected* PV-Total Added Costs	*Projected* PV-Total Reduced Returns	*Projected* PV-NET ANNUAL Return
1	782	133	108	209	598
19	-	-	-	-	0
20	-	-	-	-	0

Net Return:	**598**
MIN Rtn:	0
AVG. Rtn:	30
MAX Rtn:	598

Figure 7. MTRA Single Draw Results Table, 3 yr. analysis

Interest Rate: 0.00%

	CASH-basis analysis				
YEAR	*Projected* Total Added Returns	*Projected* Total Reduced Costs	*Projected* Total Added Costs	*Projected* Total Reduced Returns	*Projected* NET ANNUAL Return
1	780	134	109	181	625
2	790	120	102	200	609
3	730	128	107	193	558
19	-	-	-	-	0
20	-	-	-	-	0

Net Return:	**1,792**
MIN Rtn:	0
AVG. Rtn:	90
MAX Rtn:	625

Interest Rate: 10.00%

	PRESENT VALUE-basis analysis				
YEAR	*Projected* PV-Total Added Returns	*Projected* PV-Total Reduced Costs	*Projected* PV-Total Added Costs	*Projected* PV-Total Reduced Returns	*Projected* PV-NET ANNUAL Return
1	780	134	109	181	625
2	719	109	93	181	553
3	603	106	88	160	461
19	-	-	-	-	0
20	-	-	-	-	0

Net Return:	**1,640**
MIN Rtn:	0
AVG. Rtn:	82
MAX Rtn:	625

with a range of $45 to $63/ac, Figure 4. Hay harvest costs are estimated at $50/ac with a range of $26 to $76/ac. Reduced Returns are calculated based on the estimated reduced alfalfa yields and range of prices, resulting in values of $200/ton (2 tons/ac x $100/ton) for the most likely, $290 maximum (2.5 tons/ac x $145/ton), and $180 minimum (1.5 tons/ac x $90/ton), Figure 5.

For the initial analysis, Ted won't use the multi-year feature, as our focus is solely on the context of one year. He selects the checkbox under Year 1 for each budget item, ensuring it is included in the analysis. He also enters a current interest rate of 10 percent. Clicking RUN prompts the tool to evaluate alternative scenarios, generating a probability curve that displays a cumulative probability distribution of potential net benefits based on the inputs provided.

Output and Results

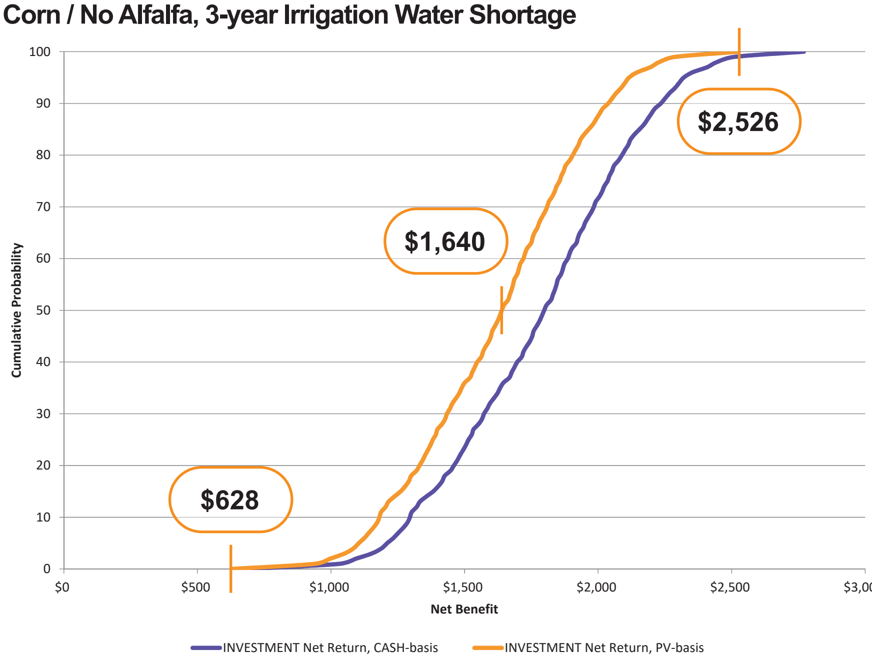
MTRA generates results are based on a thousand random simulation draws of potential outcomes, both on a Cash-basis and a Present Value (PV)-basis, which accounts for the time value of money. These results are presented in tabular form, either as a single scenario or as cumulative probabilities. An example of a single scenario shows a net return of $598/ac, Figure 6. In this particular run, the total added returns per acre were high at $782/ac, but the lost alfalfa return was also significant, at $209/ac.

While useful for analysis, a single random draw and its resulting data do not capture the full range of possible outcomes, which are crucial for Ted to make an informed decision, especially considering the water shortage may persist for more than a single year. To generate more comprehensive results, Ted selects the checkboxes for Years 1, 2, and 3 for each budget item. By clicking RUN, the tool now provides results under the assumption that the shortage will last for a total of 3 years. The updated results show a projected net return of $1,640/ac in total on a PV-basis, or an average of $547/ac/year ($1,640/3), Figure 7. On a cash-only basis (interest rate = 0.0%), the projected net return is $1,792/ac in total, or $597/ac/year ($1,792/3).

Probability Distribution

One of the most valuable outputs of the MTRA analysis is its probability curve. This graph illustrates the likelihood of various outcomes based on the data entered and the random simulation results. The most likely outcome is near the midpoint of the curve, with a 50/50 chance of occurring.

Figure 8. MTRA Cash-basis and PV-basis Probability Distribution, Water Corn / No Alfalfa, 3-year Irrigation Water Shortage



For Ted's strategy of irrigating corn but not alfalfa over 3 years, the net return is most likely to be around $1,640/ac, or an average of $546.67/ac/year, on a PV-basis, Figure 8. The highest net benefit Ted could expect from this strategy is $842.00/ac/year ($2,526 over 3 years), while the lowest would be $290/ac/year ($628 over 3 years).

Taking Another Look

The option to quickly update and rerun MTRA analysis for different scenarios is another valuable feature of the tool. Ted is uncertain whether the irrigation water shortage will last 1, 3, or more years. After reviewing the 3-year analysis results, he begins to wonder how much the outcome might change if the shortage extends to 5 years.

To explore this possibility, Ted selects the checkboxes for Years 1 through 5 for each budget item. By clicking RUN, the tool now generates results under the assumption that the shortage will last for a total of 5 years. The updated results show a projected net return of around $2,449/ac in total on a PV-basis, or an average of $490/ac/year, Figure 9. On a cash-only basis (interest rate = 0.0%), the projected net return is $2,897/ac in total, or $579/ac/year ($2,897/5).

Taking a look at the new probability curve for Ted's strategy of irrigating corn but not alfalfa over 5 years, the net return is most likely to be around $2,499/ac, or an average of around $500/ac/year ($2,499 over 5 years), on a PV-basis, Figure 10. The highest net benefit Ted could expect from this strategy is $770/ac/year ($3,851 over 5 years), while the lowest would be $191/ac/year ($957 over 5 years).

Additional considerations

Ted was concerned about the fluctuating prices of corn and alfalfa, as well as the potential for varying yields. Not knowing how these factors would influence the outcomes likely would affect decisions considered while using only the RSP tool. By using the MTRA tool to further investigate the impact of variations in each budget factor, Ted gains much more confidence in the results. He now has a clearer understanding of what to expect if the irrigation water shortage extends beyond the current season. With some experience in risk analytics, he may even consider additional strategies, such as irrigating both corn and hay crops, or exploring changes to his crop mix while the irrigation shortage persists.

Figure 9. MTRA Single Draw Results Table, 5 yr. analysis

Interest Rate: 0.00%

YEAR	CASH-basis analysis: Projected Total Added Returns	Projected Total Reduced Costs	Projected Total Added Costs	Projected Total Reduced Returns	Projected NET ANNUAL Return
1	864	133	104	228	664
2	816	120	105	222	609
3	816	131	104	235	608
4	729	128	117	228	513
5	680	124	107	195	502
19	-	-	-	-	0
20	-	-	-	-	0

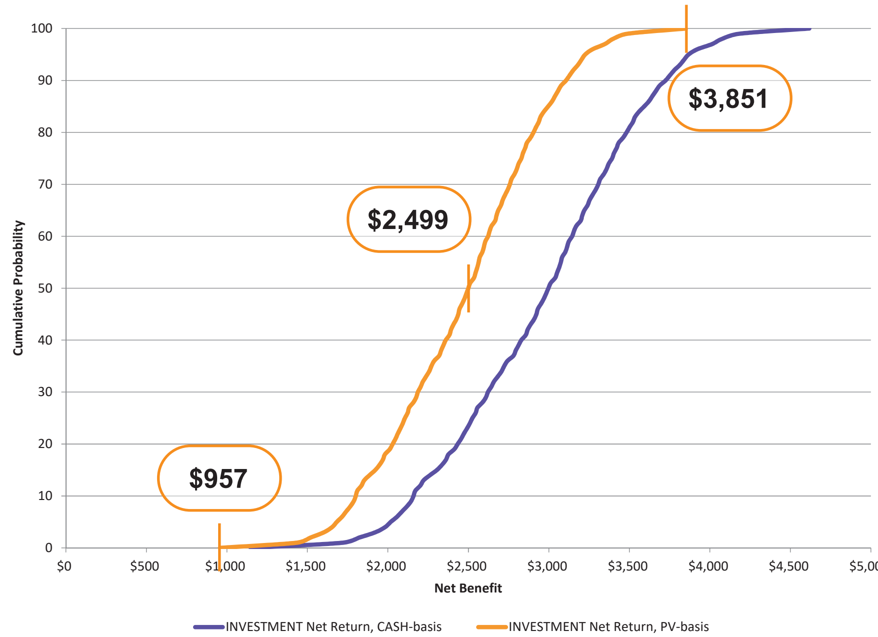
Net Return:	2,897
MIN Rtn:	0
AVG. Rtn:	145
MAX Rtn:	664

Interest Rate: 10.00%

YEAR	PRESENT VALUE-basis analysis: Projected PV-Total Added Returns	Projected PV-Total Reduced Costs	Projected PV-Total Added Costs	Projected PV-Total Reduced Returns	Projected PV-NET ANNUAL Return
1	864	133	104	228	664
2	742	109	95	202	554
3	675	108	86	194	503
4	548	96	88	171	385
5	465	85	73	133	343
19	-	-	-	-	0
20	-	-	-	-	0

Net Return:	2,449
MIN Rtn:	0
AVG. Rtn:	122
MAX Rtn:	664

Figure 10. MTRA Cash-basis and PV-basis Probability Distribution, Water Corn / No Alfalfa, 5-year Irrigation Water Shortage



For More Information

Visit RightRisk.org for more details on how the *Multi-Temporal Risk Analyzer* can assist in risk management planning for your operation. RightRisk.org offers a wide range of budgeting tools, courses, producer profiles, and other resources designed to help producers understand and manage risk, ensuring their operations thrive.

** 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.*