MARKETING AND MANAGEMENT DECISIONS UNDER CONDITIONS OF RISK AND UNCERTAINTY

by

G. Ray Prigge
Extension Economist
Farm Management Specialist

Marketing and Management Decisions Under Conditions of Risk and Uncertainty

by

G. Ray Prigge
Extension Economist
Farm Management Specialist

Introduction

Many Idaho farmers are finding it increasingly difficult to obtain a satisfactory return from the production and sale of their crop and livestock products. Rapidly increasing costs of production continue to narrow profit margins even when prices are stable. When however, product prices are depressed as they are today, profit margins tend to disappear and large losses often result.

The individual producer, because he is a member of a very competitive industry, cannot significantly affect the price he receives (except by timing and selection of alternative marketing strategies). Therefore the primary practical way that he can improve the profitability of his farm business is to increase the efficiency with which he uses land, machinery, labor, capital and other production inputs and increases his efficiency in marketing farm products.

Efficient production and marketing is a problem -- partially because of the difficulty of measuring and evaluating the impact of risk and uncertainty on the outcome of marketing strategies or productivity of input usage. For instance, if, in an average year, wheat yields increase by a measured number of bushels per acre in response to each additional 10 pound

---

Agricultural Economics Extension Series No. 325.

increment of fertilizer, it is relatively easy to determine the most profitable level of fertilizer usage. What makes the process so much more complicated, however, is the variability in yield response to added fertilizer from one year to the next. A method for assessing or evaluating this risk would allow the extension agent to assist the farmer to make more knowledgeable decisions.

Part I

Increasing Profits by Managing Risk and Uncertainty

Although prices received by farmers have increased dramatically in recent years, the price increases have been neither smooth nor predictable. Commodity prices have tended to rise rapidly with fluctuations over short periods of time. Farmers have also been faced with rapidly increasing costs of production. Since 1970, the prices paid for production inputs by U.S. farmers have increased by over 70 percent! The average price of farm land rose over 100 percent between 1970 and 1976.

Recent shortages of key production inputs, unstable supply and demand conditions, changing market price relationships, rapid technological change, shifting governmental policies and the variability of weather cause farm management decision-making to be an increasingly difficult and risky undertaking.

One technique that can be used to aid decision-making under risk is called the "payoff matrix". The "payoff matrix" tool is useful when dealing with a number of decision choices and provides a method for assessing all of the possible consequences for each separate choice. An example of a matrix is shown in Table 1.

Table 1 shows the hypothetical average expected yield of potatoes from three levels of fertilizer and three levels of irrigation water

availability. If potatoes are expected to sell for $3 per hundredweight, each of the yields are multiplied by $3 to convert the yield matrix to a gross matrix, i.e., $3 x 136 - $408 gross return per acre (Table 2).

If each unit of fertilizer costs $30, subtraction of $30 per unit from the gross returns matrix will give a return above fertilizer cost matrix, i.e., $408 - 30 = $378 returns above fertilizer (Table 3).

After calculating the above returns matrix, one thing is still needed to determine what is called the "expected payoff". That is the probabilities associated with the three levels of available irrigation water. Here "normal" available irrigation water is defined as four acre feet of water. Suppose the farmer does his homework and determines that the probability of water availability from his irrigation district (based on reservoir level, snowpack to date, intermediate and long range weather forecasts, etc.) is 60 percent or .6 for very low (60 percent of normal), 30 percent or .3 for low (80 percent of normal), and 10 percent or .1 for normal water supplies. The sum of the probabilities must add to 100 percent or one. To calculate the expected payoff each of the above nine items in the return above fertilizer cost are multiplied by the probability of their occurrence, i.e., (Table 4). Multipling the values for two and three units of fertilizer in the same manner gives a gross return above fertilizer cost matrix (Table 5). The expected payoffs calculated in Table 5 are the average return the farmer would expect from each decision choice over a number of years. For any particular year the actual return could be quite different. These expected payoffs are additional information to be used in making the cropping decision (Table 5).

Table 1: Potato Response to Fertilization

Potato Yields (in hundredweight)

Fertilizer Application (per acre)

Irrigation Water % of Normal*	1 Unit	2 Units	3 Units
60%	136	132	120
80%	154	180	190
100%	166	220	240

*normal defined as 4.0 delivered acre feet of water

Table 2: Gross Return Per Acre, Potatoes (in $)

Fertilizer Application (per acre)

Irrigation Water % of Normal*	1 Unit	2 Units	3 Units
60%	408	396	360
80%	462	540	570
100%	498	660	720

*normal defined as 4.0 delivered acre feet of water

Table 3: Return Above Fertilizer Cost

Fertilizer Application (per acre)

Irrigation Water % of Normal*	1 Unit	2 Units	3 Units
60%	378	336	270
80%	432	480	480
100%	468	600	630

*normal defined as 4.0 delivered acre feet of water

Table 4: Return Above Fertilizer Cost

Fertilizer Application (per acre)

Probability	Irrigation Water % of Normal	1 Unit				
.6	60%	$378	x	.6	=	$226.80
.3	80%	432	x	.3	=	129.60
.1	100%	468	x	.1	=	46.80
						$403.20 Expected Payoff

Table 5: Gross Return Above Fertilizer Cost

Irrigation Water % of Normal	1 Unit	2 Units	3 Units
60%	$226.80	$201.60	$162.00
80%	129.50	144.00	144.00
100%	46.80	60.00	63.00
Expected Payoff	403.20	405.60	369.00

The decision of how much fertilizer to use also depends upon the farmer's attitude. There are three general types of attitudes which people exhibit when faced with a risky decision. They are:

1. Risk Aversion - A farmer with a large family, high debts, and little savings, may be unable to take the risk of a low payoff. Note that in a year of 60 percent irrigation water the least risk of low returns is associated with the use of one unit of fertilizer (see Table 3). Even though the odds for the largest return (highest expected value) favor the use of two units of fertilizer (see Table 5), the risk averter

will choose the use of one unit.

2. Risk Neutral - A farmer who is in sounder financial condition may be risk neutral. He determines that the highest consistent profits are to be obtained by using two units of fertilizer (see Table 5), and consistently uses two units.

3. Risk Taking - A farmer in excellent financial shape or who enjoys taking a risk or wants to get the highest yield (here 240 hundredweight) will choose to use three units of fertilizer -- in effect gambling that the irrigation will be 80 percent to 100 percent of normal. Note that this strategy, in the long run, will lead to lower average returns per acre.

A variety of strategies may be used to counteract or reduce uncertainty. They include diversification of crop and livestock enterprises, flexibility in input usage, i.e., custom hire versus owning, forward marketing contracts, hedging and insurance.

In the increasingly uncertain world of the producer it is more and more certain that the traditional ways of viewing management decisions are no longer adequate. The successful farmer of the future will have to evaluate and adopt numerous new decision-making techniques just as the successful farmer of today has adopted new machines, varieties and chemicals.

Part II

An Example Problem

A farmer wishes to determine the profit maximizing use of a 150 acre irrigated field. With modification of his rotation, he can leave it in alfalfa hay for the fourth year, seed spring wheat or plant potatoes. Limited irrigation water assumptions are the same as in the preceding illustration.

Outlook and marketing information, yield and fertilizer response projections are as follows:

Table 1: Estimated Product Prices

	Minimum (25%)	Most Likely (50%)	Maximum (25%)
Wheat	$ 2.30/bu	$ 2.50/bu	$ 4.00/bu
Potatoes	2.00/cwt	3.00/cwt	4.00/cwt
Hay	35.00/ton	50.00/ton	60.00/ton

Table 2: Yields -- Response to Added Fertilizer and Available Irrigation Water

A. Wheat (bu/acre)

Fertilizer Application (per acre) at $30 Unit

Irrigation Water % of Normal*	1/3 Unit	2/3 Unit	1 Unit
60%	50	62	70
80%	56	70	80
100%	56	70	80

*Normal defined as 4.0 delivered acre feet -- thus water availability more than adequate for wheat at 80 percent of normal.

B. Potatoes (cwt/acre)

Fertilizer Application (per acre) at $30 Unit

Irrigation Water % of Normal*	1 Unit	2 Units	3 Units
60%	136	132	120
80%	154	180	190
100%	166	220	240

*Normal defined as 4.0 delivered acre feet of water.

C. Alfalfa Hay

Alfalfa Yields (in tons per acre)

Fertilizer Application (per acre) at $30 Unit

Irrigation Water % of Normal*	1/3 Unit	2/3 Unit	1 Unit
60%	4	4	3
80%	4	5	5
100%	5	6	7

*Normal defined as 4.0 delivered acre feet of water.

Table 3: Total Variable Costs (less fertilizer) Per Acre

Wheat	$ 60
Potatoes	320
Hay	108

Part III

Expected Payoffs

Using the most likely prices of $2.50/bushel for wheat and $50 /ton for alfalfa hay, the payoff matrices would be as follows:

Table 1: Wheat Response to Fertilizer

Wheat Yields (bu/ac)

Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Unit	1 Unit
60%	50	62	70
80%	56	70	80
100%	56	70	80

*Normal defined as 4.0 delivered acre feet of water.

Table 2: Gross Returns Per Acre, Wheat (in $/acre; Wheat $2.50/bu)

Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Unit	1 Unit
60%	$125	$155	$175
80%	140	175	200
100%	140	175	200

*Normal defined as 4.0 delivered acre feet of water.

Table 3: Return Above Fertilizer Cost - Wheat

Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Unit	1 Unit
60%	$115	$135	$145
80%	130	155	170
100%	130	155	170

Table 4: Calculation of Expected Return Above Fertilizer Cost - Wheat

Fertilizer Application (per acre)

Probability	Irrigation Water	1/3 Unit	
.6	60%	115 x .6 =	$ 69.00
.3	80%	130 x .3 =	39.00
.1	100%	130 x .1 =	13.00
			$121.00 Expected Payoff

Table 5: Expected Net Return Above Fertilizer Cost - Wheat

Fertilizer Application (per acre)

Probability	Irrigation Water % of Normal	1/3 Unit	2/3 Unit	1 Unit
.6	60%	$69.00	$81.00	$87.00
.3	80%	39.00	46.50	51.00
.1	100%	13.00	15.50	17.00
Expected Payoff		121.00	143.00	155.00

Table 6: Alfalfa Hay Response to Fertilizer

Alfalfa Yields (ton/acre)

Fertilizer Application $30/Unit (per acre)

Irrigation Water	1/3 Unit	2/3 Unit	1 Unit
60%	4	4	3
80%	4	5	5
100%	5	6	7

Table 7: Gross Return Per Acre, Hay (in $/acre): Hay $50/ton

Irrigation Water	1/3 Unit	2/3 Unit	1 Unit
60%	$200	$200	$150
80%	200	250	250
100%	250	300	350

Table 8: Return Above Fertilizer Cost - Hay

Irrigation Water	Fertilizer Application (per acre) 1/3 Unit	2/3 Unit	1 Unit
60%	$190	$180	$120
80%	190	230	220
100%	240	280	320

Table 9: Expected Return Above Fertilizer Cost - Hay

Probability	Irrigation Water % of Normal	Fertilizer Application (per acre) 1/3 Unit	2/3 Unit	1 Unit
.6	60%	$114	$108	$ 72
.3	80%	57	69	66
.1	100%	24	28	32
Expected Payoff		195	205	170

The expected payoffs given uncertain water supplies can be summarized as follows:

Table 10: Expected Payoff

	Units of Fertilizer 1/3 or 1	2/3 or 2	1 or 3
Wheat	$121.00	$143.00	$155.00
Potatoes	403.20	405.60	369.00
Hay	195.00	205.00	170.00

Note, however, that these are gross returns. In the short run the farmer should be interested in maximizing his return over variable costs. Subtracting the variable costs (less fertilizer) of $60/acre for wheat, $320 for potatoes and $108 for hay from the above tables yields a table of expected net payoff.

Table 11: Expected Net Payoffs

	Units of Fertilizer		
	1/3 of 1	2/3 or 2	1 or 3
Wheat	$61.00	$83.00	$95.00
Potatoes	83.20	85.60	49.00
Hay	87.00	97.00	62.00

Thus, based on the most likely prices (50 percent probability) the maximum profit over variable cost (or in the short run) would be achieved from leaving the field in hay for another year and using 2/3 unit or $20 worth of fertilizer per acre. The return would be $97 per acre above variable cost.

But, is that really the most rational decision given the information available? Remember that there was also price risk involved. Thus, one should work through this problem using expected prices (just as expected payoffs for irrigation water and fertilizer were considered).

Perhaps the easiest way is to proceed as in Table 4, i.e., multiply the probability of the price of each commodity occurring times the price e.g. for wheat:

.25 x $2.30 = $ .575

.50 x $2.50 = 1.25

.25 x $4.00 = 1.00

2.825 Expected Payoff

Following the same procedure for potatoes and hay yields these expected price levels.

Probability	Wheat	Potatoes	Hay
.25	$ .575	$ .50	$ 8.75
.50	1.25	1.50	25.00
.25	1.00	1.00	15.00
Expected Price:	2.825	3.00	48.75

These expected prices can now be used to construct Tables 2, 3, 4, and 5. Using the above prices, the expected net payoff given uncertain water supplies, can be summarized as follows:

Expected Net Payoffs*

Units of Fertilizer

	1/3 or 1 Unit	2/3 or 2 Units	1 or 3 Units
Wheat	$78.03	$104.19	$119.05
Potatoes	83.20	85.60	49.00
Hay	82.88	91.38	57.00

*See appendix for calculations.

APPENDIX

Expected Payoffs

Using the expected prices of $2.825/bushel for wheat and $48.75/ton for alfalfa hay, the payoff matrices would be as follows:

Table 1: Wheat Response to Fertilizer

Wheat Yields (bu/ac)

Fertilizer Application (per acre)

Irrigation Water % of Normal*	1/3 Unit	2/3 Units	1 Unit
60%	50	62	70
80%	56	70	80
100%	56	70	80

Table 2: Gross Returns Per Acre, Wheat (in $/acre; Wheat $2.825/bu)

Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Units	1 Unit
60%	$141.25	$175.15	$197.75
80%	158.20	197.75	226.00
100%	158.20	197.75	226.00

*Normal defined as 4.0 delivered acre feet of water.

Table 3: Return Above Fertilizer Cost

Irrigation Water % of Normal*	Probability	Fertilizer Application (per acre) 1/3 Unit	2/3 Units	1 Unit
60%	.6	$131.25	$155.15	$167.75
80%	.3	148.20	177.75	196.00
100%	.1	148.20	177.75	196.00

*Normal defined as 4.0 delivered acre feet of water.

Table 4: Expected Net Return Above Fertilizer Cost - Wheat

Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Units	1 Unit
60%	$78.75	$93.09	$100.65
80%	44.46	53.33	58.80
100%	14.82	17.77	19.60
Expected Payoff	138.03	164.19	179.05

*Normal defined as 4.0 delivered acre feet of water.

Table 5: Alfalfa Hay Response to Fertilizer

Alfalfa Yields (tons/acre)

Fertilizer Application $30/Unit (per acre)

Irrigation Water % of Normal*	1/3 Unit	2/3 Units	1 Unit
60%	4	4	3
80%	4	5	5
100%	5	6	7

*Normal defined as 4.0 delivered acre feet of water.

Table 6: Gross Return Per Acre, Hay (in $/acre at $48.75/ton)

Irrigation Water % of Normal *	1/3 Unit	2/3 Units	1 Unit
60%	$195.00	$195.00	$146.25
80%	195.00	243.75	243.75
100%	243.75	292.50	341.25

*Normal defined as 4.0 delivered acre feet of water.

Table 7: Return Above Fertilizer Cost - Hay

Fertilizer Application (per acre)

Irrigation Water % of Normal*	1/3 Unit	2/3 Units	1 Unit
60%	$185.00	$175.00	$116.25
80%	185.00	223.75	213.75
100%	233.75	272.50	311.25

*Normal defined as 4.0 delivered acre feet of water.

Table 8: Expected Return Above Fertilizer Cost - Hay

Probability	Irrigation Water % of Normal*	Fertilizer Application (per acre) 1/3 Unit	2/3 Units	1 Unit
.6	60%	$111.00	$105.00	$ 69.75
.3	80%	55.50	67.13	64.13
.1	100%	24.38	27.25	31.12
Expected Payoff		190.88	199.38	165.00

*Normal defined as 4.0 delivered acre feet of water.

Potatoes

The expected price and most likely price for potatoes is $3.00. Therefore, the earlier analysis is still valid.

Table 9: Expected Payoffs

	Units of Fertilizer 1/3 or 1	2/3 or 2	1 or 3
Wheat	$138.03	$164.19	$179.05
Potatoes	403.20	405.60	369.00
Hay	190.88	199.38	165.00

Subtracting the variable costs (less fertilizer) of $60/acre for wheat, $320 for potatoes and $108 for hay from the above tables yields a table of expected net payoff.

Table 10: Expected Net Payoffs

	Units of Fertilizer 1/3 or 1	2/3 or 2	1 or 3
Wheat	$78.03	$104.19	$119.05
Potatoes	83.20	85.60	49.00
Hay	82.88	91.38	57.00

Thus, based on expected prices the maximum profit over variable cost would be achieved from growing spring wheat on the 150 acre field using one unit or $30 worth of fertilizer per acre. The return would be $119.05 per acre above variable cost. Note that this is an improvement in net return of $27.67 per acre greater than would have been achieved by selecting the 2/3 units of fertilizer on hay that was suggested earlier when the price variability was ignored.