TEACHING DECISION MAKING UNDER RISK AND UNCERTAINTY TO FARMERS*

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Abstract:

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and Uncertainty to Farmers

A manager's central role is making choices among uncertain outcomes. A teaching approach is reported which uses decision trees and portable computer terminals to help managers analyze the component parts of a decision; clarify the risk involved in each action; and help to analyze that risk in a systematic, understandable manner. The analysis--whether or not to graze stocker cattle on wheat--embodies production and marketing risk for both cattle and wheat.

Key Words: decision trees, wheat, stocker grazing, risk and uncertainty, portable terminals.

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There have been relatively few Extension attempts to teach decision making under risk and uncertainty to farmers. The work of Black in incorporating probabilities into outlook work, and Kadlec's suggested farming strategies under uncertainty are notable exceptions. Undoubtedly there are others, but efforts to teach risk management concepts to farmers are hardly the main-stream effort of most Extension professionals.

The Extension educational base needs broadening to include techniques for handling risk and uncertainty. Farmers have always faced multiple risks, but especially during the 1970's rising costs and roller coaster product prices have magnified the effect of both "right" and "wrong" decisions. In this climate, farmers need decision making aids which permit them to assimilate more information and incorporate it with their traditional management "rules-of-thumb."

This paper reports an analytical and educational approach with which one can reach farmers, even small ones, and teach them some modern decision making techniques. Decision trees are the core of this approach because they take into account "the simplifying procedures people use in 'real life' decision making" [Gladwin, p. 881]. Interactive computer routines and portable terminals make it possible to use farmers' own problems as teaching tools. The analysis--whether or not to graze stocker cattle on wheat--embodies production and marketing risk for both cattle and wheat.

THE DELIVERY SYSTEM

Extension has the role of providing information for decision making and has responsibility for improving farmers' decision making skills. The framework is present, but not always effectively used [Kolmer]. A chronic shortcoming is that "...we are reaching relatively few of the small and less educated farmers" [Eisgruber, p. 933].

An effective delivery system should be "close by and convenient" [Kolmer, p. 916]. This means involving County Extension professionals, who are on-site salesman for local education programs. Their bread-and-butter tool is a single meeting, usually held at night, and oriented to a particular topic. One-night stands are decried in other contexts, but County professionals who use them know that meetings must be held near an important segment of their clientele. Large size farms can afford specialized managers who may fly to specialized symposia to obtain the latest information, but that is not an option for the typical owner-operator who is both decision-maker and workforce. Meetings held in their area offer the best hope of getting the latest information to them.

This educational approach was designed for presentation at one-shot farmer meetings organized by County Extension agents.

THE STOCKER CATTLE DECISION

Depending on the time of year when the decision is to be analyzed, the questions may be: whether to plant wheat early or late; whether or not to buy or sell cattle--both in the fall and in the spring; or whether to graze all, none, or part of the wheat with stockers. The program can address any of these, but the example given herein analyzes a typical spring decision--what to do with stocker cattle that are on hand. The analytical procedure was first to estimate the returns to wheat alone, then wheat plus the March sale of stockers, then a mixture of harvesting some wheat and grazing out the rest, selling stockers in May. The output format allows decisions based on expected values or on the probability of receiving a target income level.

TEACHING PROCEDURE[1]

The teaching objectives for the meeting were to show producers the value of incorporating yield and price uncertainty into their decisions, and to illustrate a procedure for doing so. An overview of past yield and price fluctuations for cattle and wheat showed that making only single value estimates (typical budgets) ignores more information than the wise decision-maker is willing to forego. The other introductory point was that different managers, because of personal preferences, could quite logically make different decisions even when faced with the same external conditions.

The logic of incorporating uncertainty into a decision was illustrated with a decision tree for a range of wheat incomes (Figure 1). Beginning with the likely variation in yields, the decision tree was developed a step at a time. Experiment station results, modified by weather information, provided the yield estimates shown on the tree.

Yield	Yield Probability	Crop Sell/Pr	Price Probability	Crop Income/AC	Joint Probability %
		2.40	(.2)	71.50	3.76
35	(.188)	2.15	(.6)	62.75	11.28
		1.90	(.2)	54.00	3.76
		2.40	(.2)	52.30	12.50
27	(.625	2.15	(.6)	45.55	37.50
		1.90	(.2)	38.80	12.50
		2.40	(.2)	33.10	3.74
19	(.187)	2.15	(.6)	28.25	11.22
		1.90	(.2)	23.60	3.74

EXPECTED VALUE/AC = $45.57

Figure 1.--Expected wheat incomes, considering a range of yields, prices, and their probabilities

A discussion of price projections followed the yield estimates. The dialogue surrounding the price branches of the tree proved to be an effective means of conveying outlook information to a production-oriented audience. As expected, farmers were considerably less comfortable with establishing both price levels and their probabilities than was the case with yields.

Calculating incomes was a prelude to explaining the joint probabilities, or likelihood, or obtaining those incomes. The incomes shown in Figure 1 are price times yield minus an arbitrary harvest cost of $12.50 per acre. This was the only cost deducted because this example considered the disposition of a crop that was already established.

Joint probabilities were calculated and explained as the "odds" or chances of obtaining the given incomes with the indicated assumptions about yields, prices, and probabilities. At present, it seems that farmers have been less bothered by the joint probabilities than have Extension workers.[2] Perhaps farmers have failed to grasp their implications, but it is at least equally plausible that Extension workers are less accustomed to thinking in a decision-theoretic manner than are farmers.

Farmer interest has centered on the joint probabilities, but expected values were used to compare incomes obtainable from the different alternatives. The concentration in the meeting was on the decision making process more than on the expected values, however. As can be seen in Figure 1, the expected value ($45.57) is almost identical with the value ($45.55) which might have been obtained by using enterprise budgets. So for wheat, with these yields, prices, and their probabilities, the tree approach provides more information, but not necessarily any different "answer" than budgeting can give.

The Data

The data required for analyzing stocker alternatives are in Table 1. Any non-zero element in the matrix can be changed

Table 1.--Data and probablities for wheat and stocker grazing, North Central Oklahoma

Item	Data			Probabilities		
	Good	Fair	Poor	Good	Fair	Poor
1. Grain yield	35.00	27.00	19.00	0.188	0.625	0.187
2. Grain price	2.40	2.15	1.90	0.200	0.600	0.200
3. Grazing days	80.00	65.00	50.00	0.188	0.625	0.200
4. Ave. daily grain	2.00	1.75	1.50	0.000	0.000	0.000
5. # Stockers/Ac	0.40	0.40	0.40	0.000	0.000	0.000
6. Stocker price-sell	45.00	41.00	37.50	0.300	0.500	0.200
7. % Acres harvested	0.80	0.73	0.60	0.000	0.000	0.000

to suit the user. The first two rows pertain to wheat, and were the coefficients shown on the decision tree. Rows 3, 4, and 5 indicate the expected conditions for grazing. Probabilities in row 3 are for total stocker production which involves grazing days, daily gains, and stocking rates. Stocker prices and probabilities are in row 6. Wheat prices and yields, and stocker prices and gains, were assumed to be independent events. Row 7, the percent acres harvested, is used only in the routine which calculates returns to a mix of grazing and harvesting wheat. Although not shown, variable costs were also obtained for the various options and used in estimating returns above cost.

The relationship between wheat yields and grazing gains is difficult to quantify both because data are limited and because a "good" year for wheat yields may not provide "good" gains for cattle which graze that wheat. Based primarily on a survey by Walker and Plaxico, supplemented with correlations of grain and forage yield from limited experimental data, the rather tenuous assumption is made that wheat yields are directly linked to grazing yields.

The probabilities of grain yields and grazing days in Table 1 are identical, but they can be, and occasionally have been, specified differently by various users. When either the harvest only or the total graze-out options were analyzed, the program utilized the probabilities in rows 1 and 3 independently. However, when a mix of harvesting and grazeout was desired, the program invoked the direct linkage assumption, and both grain yields and grazing gains were weighted by the probabilities associated with grazing gains (row 3).

Comparing Alternatives

Incomes in Table 2 were from selling stockers in March and harvesting all the wheat. The first three columns repeat the results of the harvest only analysis of Figure 1. For the spring decision, net income per acre from fall stockers is known ($12.30), and it is added to wheat incomes to obtain the incomes per acre shown in the forth column. Expected value per acre is the incomes per acre weighted by the probabilities, or $57.87 per acre.

The most complex analysis was a mix of grazeout and harvest (Table 3). Eighty-one outcomes are possible when three yield levels and three prices are considered for both cattle and wheat. Thus some simplification is necessary to retain the interpretational ease afforded by a tree with nine outcomes. Since grain yields are assumed directly correlated with grazing gains, the number of outcomes is reduced to 27. Deriving a weighted wheat price (the sum of probabilities times prices) permits a tree with nine outcomes. The weighted wheat price times wheat yields times percent acre harvested produces the "Value Grain" column in Table 3. Stocker weights were calculated for the different gains and multiplied by the respective prices to get stocker incomes per head for the March to May period. Then stocker incomes from the fall ($12.30 per acre, $30.75 per head) were added to balance this internal transaction, and the resulting incomes per head were displayed to help farmers who think in those terms.[3] Partial budgeting logic dictates ignoring stocker incomes for the alternatives of selling or retaining fall steers, since they are the same for both. However, much farm planning relies on cash flows, so the option of listing them permits a measure of net incomes to be seen for the different alternatives. Incomes per acre are "Value Grain" added to per acre stocker returns.

Comparing the analysis in Tables 2 and 3 indicates that, if profit maximization was the goal, March stockers should be sold and all the grain should be harvested ($57.87 > $56.41). However, a decision-maker who had a "safety-first" criterion might decide to keep the stockers and graze out part of the

Table 2.--Wheat yields, prices, incomes, and probabilities, North Central Oklahoma

	Volume	Crop sell pr	Crop income/ac	Income per ac	Joint prob.
GOOD yield, GOOD price	35.0	$2.40	$71.50	$83.80	3.76%
GOOD yield, FAIR price	35.0	$2.15	$62.75	$75.05	11.28%
GOOD yield, POOR price	35.0	$1.90	$54.00	$66.30	3.76%
FAIR yield, GOOD price	27.0	$2.40	$52.30	$64.60	12.50%
FAIR yield, FAIR price	27.0	$2.15	$45.55	$57.85	37.50%
FAIR yield, POOR price	27.0	$1.90	$38.80	$51.10	12.50%
POOR yield, GOOD price	19.0	$2.40	$33.10	$45.40	3.74%
POOR yield, FAIR price	19.0	$2.15	$28.35	$40.65	11.22%
POOR yield, POOR price	19.0	$1.90	$23.60	$35.90	3.74%

Expected Value/Ac = $57.87

Table 3.--Wheat and stocker incomes, harvest and graze-out mixture, North Central Oklahoma

Gains yield	Stocker price	Value grain	Stocker weight	Stocker income/hd	Income per ac	Joint prob.
GOOD	GOOD	$50.20	710	$99.84	$90.14	5.64%
GOOD	FAIR	$50.20	710	$71.58	$78.33	9.40%
GOOD	POOR	$50.20	710	$46.86	$68.94	3.76%
FAIR	GOOD	$33.25	664	$80.03	$65.26	18.75%
FAIR	FAIR	$33.25	664	$53.62	$54.70	31.25%
FAIR	POOR	$33.25	664	$30.50	$45.45	12.50%
POOR	GOOD	$17.01	625	$63.59	$42.44	5.61%
POOR	FAIR	$17.01	625	$38.71	$32.49	9.35%
POOR	POOR	$17.01	625	$16.94	$23.79	3.74%

Expected Value/Ac = $56.41
Expected Stocker Weight = 665
Expected Stocker/Ac = 0.4

wheat. If, for example, he needed to make at least $60 per acre, Grazeout-Harvest would provide a 37.55 percent chance of making at least that much, whereas selling March stockers and harvesting wheat has a 31.3 percent chance of making that much income.

Five common spring decision analyses, including those shown previously, are summarized in Table 4. They illustrate the diversity of opinions possible when uncertainty and different managerial objectives are considered. Rows 1 and 2 pertain to farmers who did not buy stockers in the fall, whereas options 3, 4, and 5 were open to farmers who had fall stockers.

Table 4.--Expected values, income ranges, and probabilities of making more than $60 per acre from wheat and stocker alternatives, North Central Oklahoma[4]

Row #	Decision	Expected value	Income range	Prob. inc. ≥ $60/Ac
		$	$	%
1	Harvest wheat only	45.57	23.60 to 71.50	15.04
2	Purchase stockers and graze out	21.92	-50.65 to 97.62	37.55
3	Sell fall stockers and harvest all wheat	57.87	35.90 to 83.80	31.3
4	Keep fall stockers and harvest some wheat	56.41	16.94 to 99.84	37.55
5	Keep fall stockers, purchase more, graze wheat out	40.06	-32.61 to 115.87	33.79

Wheat only (row 1) might have been chosen by the farmer who had no fall stockers, and was not inclined to take the risk associated with purchasing stockers (-$50.65 in row 2). Despite some potential losses associated with purchasing stockers and grazing wheat out, row 2 offered the highest probability of being able to make at least $60 per acre for the farmer who had no fall stockers. Choosing the highest expected value would indicate choosing row 3. Another farmer with a similar situation might opt for row 4, which had a higher probability of obtaining $60 income per acre, even though both the minimum income and the expected value were lower than row 3. A "plunger," who placed more weight on the highest possible income per acre, might decide to keep his fall stockers, buy more, and graze the wheat out (row 5).

Thus, in one audience, there have been farmers who chose all five situations, based on a consideration of the riskiness of the alternatives weighed against their personal risk preferences. A teaching format which includes risk permits one to retain the attention of the whole audience by approximating their individual decision making processes. It has been interesting to observe farmers defending their different choices, based on identical analyses.

Farmers' Problems

The diversity of opinions possible with the example data illustrate why farmers appreciated the chance to have their own (or very similar) situations analyzed. To begin eliciting farmers' data, Table 1 is shown again, with a discussion of the differences between their local situation and the data shown. Then a situation was selected which the group would like analyzed. Normally an individual, more vocal than the rest, agreed to provide data for his situation.

Farmers' management "rules-of-thumb" were directly incorporated into the teaching process at this point. Wheat yields, stocking rates, grazing days, daily rates of gain, prices, and the way these relationships are combined in their own analytical processes all get an airing here. Debate sometimes raged among farmers about some of these relationships. From a teaching standpoint, the problem was to control the debate enough to keep the emphasis on the decision-making process. The ability to repeat an analysis with a different farmer's assumptions was especially valuable in showing how different viewpoints (or information) about markets or cattle gains could reverse a decision.

As obtained, the data were entered on the portable terminal by one of the two teachers, and by the time discussion had died down, the results had been transferred to a transparency and shown immediately to the audience. Major arguments were "settled" by changing the debated coefficients and repeating the analysis.

CONCLUDING REMARKS

A manager's central role is making choices among uncertain outcomes. In that role, he needs decision making aids which permit him to assimilate more information. And in an Extension teaching environment where audiences are not captive, uncertainty needs to be explicitly treated, and repeated exposure to students is a rarity, the instructor needs help.

The decision tree approach, coupled with interactive programs and portable computer terminals, is a tool that can assure student/student and student/teacher interaction. And it saves wear and tear on the teacher. The audience provides localized physical coefficients. The audience corrects the data input provided by other farmers. Repeating analyses with different farmers' assumptions reemphasizes the decision-making process, and illustrates the role of information in decision making.

Programs such as this one, focusing on the decision-making process itself, and adding the treatment of yield and price uncertainty to farmers' "rules-of-thumb" procedures can aid farmers as they make choices among uncertain outcomes and commit present resources to an unknowable future.

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FOOTNOTES

[1]This teaching approach was used with 4 different groups totalling 178 farmers. The audiences ranged in size from 12 to 99; the smallest was a cosmopolitan board of directors of a commodity association, the others were typical farmer audiences generated by County Extension agents in rural counties.

[2]A total of 61 farmers completed evaluation forms. Of these, 39 or 64 percent, felt that the joint probabilities were the "strongest point of the program." Only 3 respondents "didn't understand joint probabilities." Colleagues had repeatedly warned that farmers would not understand the concept.

[3]McCarl, et al, argue for the inclusion of data "which are not necessary to the solution of the problem, yet contribute to farmer's understanding of the output" [p. 24].

[4]In addition to those noted in the text, the assumptions were: 1.8 stockers per acre for the spring period; a .5% death loss on owned stockers; a 1% death loss on purchased stockers.