# Incorporating Uncertainty into Extension Decision Aids: An Overview of Four Approaches

*by*
*Thomas O. Knight, Kathryn A. Kubiak and Bruce A. McCarl*

In the past 20 years various analytical approaches for decision making under uncertainty have become important methods in agricultural economics research focusing on decision problems of agricultural producers. These methods have, however, been incorporated into extension programs at a much slower pace. In reporting the results of a national survey of farm management instructors and extension specialists conducted in 1975, Walker and Nelson concluded that: "Overall, very little evidence was found of significant efforts in either classroom teaching or extension to apply the concepts of decision making under uncertainty to farm management."

This survey was part of a special needs project sponsored by the Federal Extension Service and conducted jointly by Oklahoma State and Oregon State Universities. The objective of the project was to bridge a gap between theory and practice in decision making under uncertainty (Walker and Nelson). Among the project outputs were three computerized decision aids designed to assist agricultural producers in evaluating management decisions (Anderson and Holt; Hardin; Nelson, Faus and Powers). These models were the first generation of computerized extension decision aids designed for evaluating decisions under uncertainty.

A decade later, concepts and procedures for decision making under uncertainty still have not been fully incorporated into extension programs and decision aids. Recently, Knight and Kubiak studied 41 extension decision aids developed to assist agricultural producers in formulating bids for the Conservation Reserve and Milk Production Termination Programs. They found that none of these procedures incorporated uncertainty directly into the analysis, although supporting materials clearly recognized that uncertainty was important in these decisions.

Although methods for decision making under uncertainty have not made their way into the majority of extension farm management decision aids, several significant efforts in this direction have been made or are currently underway. This paper overviews the products of four of these efforts. They are:

(a) the Whole Farm Risk-Rating Microcomputer Model (Anderson and Ikerd),

(b) the Agricultural Risk Management Simulator, ARMS. (King 1986),

(c) the Virginia Polytechnic Institute and State University (VPI) Crop Insurance Evaluation program (SriRamaratnam, Moore and Kramer), and

(d) the Commodity Program Analyzer (Knight, Kubiak and McCarl).

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*Thomas O. Knight is an assistant professor, Kathryn A. Kubiak is a research assistant and Bruce A. McCarl is a professor, Department of Agricultural Economics, Texas A&M University System*

Emphasis is placed on the way uncertainty is incorporated into the analysis. Particular attention is given to the approaches taken in eliciting probabilistic information from and presenting it to the user. Since this Committee is made up of people who do research in decision making under uncertainty, the the final section of the paper discusses research which could contribute to improved approaches for delivering these methods to extension audiences.

## THE WHOLE FARM RISK-RATING MODEL

The Whole Farm Risk-Rating Model evaluates both production and marketing decisions. Among the production decisions that can be analyzed are single enterprise profitability under alternative production systems and enterprise mix selection. Alternative marketing strategies include (a) cash sale, (b) hedging of sale price, (c) sale by basis contract and (d) forward cash contracting.

Figure 1 shows the basic input section for an example 500 acre wheat enterprise. Probabilistic information may be entered for each marketing alternative and for per acre yield. Cost estimates are nonprobabilistic. The required probabilistic data include expected, optimistic and pessimistic values for each random variable included in the analysis. The pessimistic value is defined as the level that there is a 1 in 6 chance of the random variable falling below. Similarly, the optimistic value is the level that the user believes there is a 1 in 6 chance of the random variable exceeding. Thus, the probabilities used in the model are the user's subjective assessments of three fractiles of the distributions of the random variables. In addition to this probabilistic information the user is also asked to assess the correlation coefficient between price and yield.

Figure 1. Basic Input Section for Risk-Rating Model

| Wheat | | 1 | |
|---|---|---|---|
| Number of Acres > | 500.00 | Average Yield/Acre | 35.00 |
| % Crop Hedged | 0.00 | Optimistic (1 in 6) | 35.00 |
| Hedge Price | 0.00 | Pessimistic(1 in 6) | 35.00 |
| Expected Basis | 0.00 | $ of Nitrogen/Acre | 7.16 |
| Pessimistic(1 in 6) | 0.00 | $ of Mixed Fertilizer/Acre | 12.00 |
| Optimistic (1 in 6) | 0.00 | $ of Lime/Acre | 0.00 |
| Hedge Cost | 0.00 | $ of Seed or Plants/Acre | 20.00 |
| % Crop Sold by Basis Contract | 0.00 | $ of Chemical/Acre | 20.00 |
| Expected Contract Price | 0.00 | $ of Fuel & Oil/Acre | 5.11 |
| Optimistic (1 in 6) | 0.00 | $ of Repairs/Acre | 1.76 |
| Pessimistic(1 in 6) | 0.00 | $ of Mrkting & Hrvsting/Acre | 16.00 |
| % Crop Forward Contracted | 0.00 | % Operating Capital Borrowed | 80.00 |
| Contract Price | 0.00 | Interest Rate | 13.00 |
| Average Price/Unit | 2.30 | Other Fixed Costs/Acre | 0.00 |
| Optimistic (1 in 6) | 4.00 | Relationship:Yield-Price | 0.00 |
| Pessimistic(1 in 6) | 1.90 | :Cash Price-Basis. | 0.00 |

Strong distributional assumptions are made in incorporating uncertainty into the analysis. Yields are assumed to be normally distributed while price distributions are assumed to be log-normal. Total revenue is assumed to be normally distributed with mean and standard deviation derived from the estimated means, standard deviations and correlation coefficients of the underlying price and yield distributions.

Other inputs required for the Whole Farm analysis are: (a) total fixed costs, (b) value of all assets, (c) whole farm debt, (d) desired return on equity capital, and (e) the correlation coefficient between net returns for each pair of enterprises. Example whole farm analysis results for a farm plan made up of a 500 acre wheat enterprise and a 500 acre grain sorghum enterprise are shown in figure 2. (Single enterprise results are presented in similar format). The upper section of figure 2 gives expected total returns (receipts), expected total variable costs and expected fixed cash costs. Optimistic, expected and pessimistic returns above variable costs and above total cash costs are in the center section. The lower section gives the probability of total farm returns (receipts) exceeding variable costs and total farm cash costs, as well as the probability of a return to equity greater than that specified by the user.

The Risk-Rating Model is programmed in the Basic language and is available for Radio Shack, Apple IIe (configured with 64K RAM and Microsoft CP/M) and IBM compatible microcomputers. The model requires 64K of random access memory. A Lotus 1-2-3 spreadsheet version of the model is also available (Anderson and Ikerd).

The same basic procedure of the Risk-Rating Model has been incorporated into enterprise budget templates distributed by the Georgia Agricultural Extension Service. This application, however, presently facilitates single enterprise analysis only.

Figure 2. Example Whole Farm Analysis Section for Risk-Rating Model

Results for: Whole Farm

| | | |
|---|---|---|
| THE EXPECTED TOTAL RETURNS ARE | $ | 97,360 |
| THE EXPECTED TOTAL VARIABLE COSTS ARE | | 90,346 |
| THE EXPECTED TOTAL FIXED CASH COSTS ARE | | 20,000 |

| Returns Above Variable Cost | | Returns Above Total Cash Cost | |
|---|---|---|---|
| Optimistic = | 53,510 | Optimistic = | 33,510 |
| Expected = | 7,013 | Expected = | -12,987 |
| Pessimistic= | -39,484 | Pessimistic= | -59,484 |

| | |
|---|---|
| Probability of Total Farm Returns being >= Variable Costs | = 56% |
| Probability of Total Farm Returns being >= Total Farm Cash Costs | = 39% |
| Probability of return to equity being >= 5% | = 30% |

## ARMS

Like the Risk-Rating model, ARMS is designed to evaluate both production and marketing decisions. Specifically, the model generates probability distributions of net cash flows associated with alternative enterprise combinations, levels of multiple peril crop insurance coverage and cash contracting. The model is divided into three major sections: (a) the Farm and Enterprise data entry section (b) the Yield and Price Probability section (c) the Strategy Evaluation section. The Yield and Price Probability and Strategy Evaluation sections are described here because they are the sections in which probabilistic information is elicited and summarized.

The Yield and Price Probability section permits the user to select among four alternative ways to enter yield data for up to four crops (four is the maximum number of enterprises that can be evaluated). The alternatives are (a) constant yield, (b) random yields based on 5 to 16 historical observations, (c) random yields derived from subjective estimates of parameters of a normal distribution and (d) random yields from subjective assessments of percentiles of the yield distribution. In all but the constant yield case, a screen like that in figure 3 appears to permit the user to modify his/her yield assessments. Thus, a yield distribution based on historical data may be modified to be consistent with the users' subjective yield expectations. Modifying a distribution initially based on assessed parameters of a normal distribution could, of course, result in a final distribution that is not normally distributed.

Figure 3. Screen Presenting Percentiles Derived from Historical Data

CROP YIELD INFORMATION

Crop: COTTON — Data Entry Option: Historical

| | Implied | Modified | Notes |
|---|---|---|---|
| Minimum | 256.25 | 256.25 | |
| 1st percentile | 263.40 | 263.40 | The YIELD levels in the |
| 5th percentile | 291.98 | 291.98 | "Implied" column describe the |
| 10th percentile | 321.15 | 321.15 | probability distribution |
| 20th percentile | 347.64 | 347.64 | implied by the data you have |
| 30th percentile | 376.32 | 376.32 | entered. |
| 40th percentile | 400.14 | 400.14 | |
| 50th percentile | 427.60 | 427.60 | If you wish, you can modify |
| 60th percentile | 462.36 | 462.36 | the distribution by entering |
| 70th percentile | 491.77 | 491.77 | revised YIELD levels in the |
| 80th percentile | 527.50 | 527.50 | "Modified" column. |
| 90th percentile | 636.87 | 636.87 | |
| 95th percentile | 672.60 | 672.60 | Press F6 to set the Modified |
| 99th percentile | 693.75 | 693.75 | equal to the Implied values. |
| Maximum | 693.75 | 693.75 | |

After all yield distributions are completed, the user chooses among four ways of entering price information. Three of the alternatives are identical to those used for yields. These are: (a) constant prices, (b) random prices derived from elicited parameters of normal distributions, and (c) random prices based on assessed percentiles of the price distribution. The fourth method for entering price information develops price distributions from commodity futures option values. This procedure is described in King and Fackler.

When the price data for all enterprises have been entered, the procedure requests price and yield-price correlation coefficients for each pair of enterprises. The program then uses King's procedure (King 1979) to perform a random draw of up to 250 observations on prices and yields. These, prices and yields, along with cost and other general farm data, form the basis for the strategy evaluations.

The Strategy Evaluation section permits the user to specify three alternative crop mix, crop insurance, and forward pricing strategies per run. After strategy specifications have been chosen for all enterprises, the complete strategies are displayed in a summary screen. Figure 4 is the screen which summarizes the analysis for an example wheat, corn, grain sorghum and cotton farm. The two strategies evaluated are for alternative crop mixes. Strategy 1 is for 250 acres of each crop while strategy 2 is for 500 acres of corn, 250 acres of cotton and 250 acres of wheat. Neither strategy includes either forward pricing or crop insurance. Percentiles as well as means and standard deviations of the net cash flow cumulative distribution for each strategy are presented in figure 4. Alternative strategies can be evaluated by respecifying the crop mix, crop insurance and forward contracting selections.

Figure 4. ARMS Analysis Summary for Example Farm Strategy

| NET CASH FLOW CUMULATIVE DISTRIBUTIONS ($/year) | | | |
|---|---|---|---|
| | Strategy 1 | Strategy 2 | |
| Minimum | -35451.21 | 4955.79 | . |
| 1st Percentile | -29590.50 | 7248.46 | . |
| 5th Percentile | -25049.65 | 12181.36 | . |
| 10th Percentile | -15287.45 | 16837.38 | . |
| 20th Percentile | -6500.06 | 21327.64 | . |
| 30th Percentile | 49.38 | 24812.71 | . |
| 40th Percentile | 5148.77 | 28739.78 | . |
| 50th Percentile | 11217.46 | 32305.25 | . |
| 60th Percentile | 15980.00 | 35997.23 | . |
| 70th Percentile | 20986.33 | 40040.64 | . |
| 80th Percentile | 28354.64 | 45031.93 | . |
| 90th Percentile | 40148.13 | 60320.21 | . |
| 95th Percentile | 53278.75 | 63645.23 | . |
| 99th Percentile | 61464.22 | 68108.95 | . |
| Maximum | 65824.20 | 70844.29 | . |
| | | | |
| Mean | 11518.69 | 34196.39 | . |
| Std. Deviation | 21566.86 | 15149.07 | . |

ARMS is a compiled program written in the Turbo-Pascal programming language. Speed Screen (Version 1.00) from The Software Bottling Company is used to generate the input and output screens. The program is available for IBM PC, XT, AT (or compatible) microcomputers using MS-DOS or PC-DOS version 2.0 or higher operating systems with a minimum of 256K of random access memory. Additional hardware requirements are provided in the ARMS user's manual (King, 1986).

## THE VPI CROP INSURANCE EVALUATION MODEL

The Crop Insurance Evaluation Model is in fact three separate electronic spreadsheets. These spreadsheets are designed to evaluate the purchase of multiple peril crop insurance on (a) corn or sorghum, (b) wheat, and (c) soybeans. Yield uncertainty is incorporated into the analysis but price uncertainty is not. The model does not accommodate whole farm analysis.

Subjective yield distributions are used in this model. These distributions are elicited using the fixed-intevnal elicitation approach shown in figure 5. Probabilities are derived by assessing the chance in 50 of a yield in each of 15 prespecified ranges. The program permits the user to view a graphical presentation (histogram) of the assessed yield probabilities and to revise his/ her assessments.

Results are summarized in screens like that in figure 6. Per acre net income for each yield level and insurance option on an example grain sorghum farm are shown. Probabilities assigned to the yield intervals are also given. A second summary screen (not shown) gives average (expected) and minimum per acre net income for each alternative as well as the probability of a loss.

Figure 5. Screen for Entering Yield Probabilities in the Crop Insurance Evaluation Model

* * * * * * YOUR ESTIMATE FOR CORN YIELDS * * * * * * * *

| TABLE 1A | YIELD RANGE | RANGE MID'PT | YOUR ESTIMATE | YOUR %PROB. | |
|---|---|---|---|---|---|
| | 0-7 | 5 | 2 | 4.0 | |
| Use the | 8-12 | 10 | 3 | 6.0 | |
| [ALT]Key | 13-17 | 15 | 3 | 6.0 | |
| and [A] | 18-22 | 20 | 4 | 8.0 | Enter |
| to add | 23-27 | 25 | 8 | 16.0 | YOUR |
| the nos. | 28-32 | 30 | 12 | 24.0 | yield |
| to 50. | 33-37 | 35 | 15 | 30.0 | probability |
| | 38-42 | 40 | 3 | 6.0 | estimates |
| | 43-47 | 45 | 0 | 0.0 | & then |
| | 48-52 | 50 | 0 | 0.0 | press the |
| | 53-57 | 55 | 0 | 0.0 | [F9] key |
| | 58-62 | 60 | 0 | 0.0 | to recal- |
| | 63-67 | 65 | 0 | 0.0 | culate |
| | 68-72 | 70 | 0 | 0.0 | |
| | > 72 | 75 | 0 | 0.0 | |
| | | TOTAL | 50 | 100 | 30 = APH |
| | YOUR EXPECTED YIELD = | | | 27 | BUSHELS |

* * * * * * * * * * * * * * * * * * * * * * * * * * * * *

Figure 6. Summary Screen 1 for Crop Insurance Evaluation Model

| YIELD MIDPOINT | YOUR % PROB. | NO INS. BOUGHT | PER ACRE ______ $1.25 | $1.50 | $2.00 | ______ $1.25 | $1.50 | $2.00 | ______ $1.25 | $1.50 | $2.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 4.0 | -55 | -44 | -42 | -38 | -41 | -38 | -32 | -39 | -36 | -29 |
| 10 | 6.0 | -45 | -41 | -40 | -38 | -37 | -35 | -32 | -35 | -33 | -29 |
| 15 | 6.0 | -35 | -37 | -37 | -38 | -33 | -33 | -32 | -31 | -31 | -29 |
| 20 | 8.0 | -25 | -27 | -27 | -28 | -29 | -29 | -31 | -28 | -28 | -29 |
| 25 | 16.0 | -15 | -17 | -17 | -18 | -19 | -19 | -21 | -21 | -22 | -24 |
| 30 | 24.0 | -5 | -7 | -7 | -8 | -9 | -9 | -11 | -11 | -12 | -14 |
| 35 | 30.0 | 5 | 3 | 3 | 2 | 1 | 1 | -1 | -1 | -2 | -4 |
| 40 | 6.0 | 15 | 13 | 13 | 12 | 11 | 11 | 9 | 9 | 8 | 6 |
| 45 | 0.0 | 25 | 23 | 23 | 22 | 21 | 21 | 19 | 19 | 18 | 16 |
| 50 | 0.0 | 35 | 33 | 33 | 32 | 31 | 31 | 29 | 29 | 28 | 26 |
| 55 | 0.0 | 45 | 43 | 43 | 42 | 41 | 41 | 39 | 39 | 38 | 36 |
| 60 | 0.0 | 55 | 53 | 53 | 52 | 51 | 51 | 49 | 49 | 48 | 46 |
| 65 | 0.0 | 65 | 63 | 63 | 62 | 61 | 61 | 59 | 59 | 58 | 56 |
| 70 | 0.0 | 75 | 73 | 73 | 72 | 71 | 71 | 69 | 69 | 68 | 66 |
| 75 | 0.0 | 85 | 83 | 83 | 82 | 81 | 81 | 79 | 79 | 78 | 76 |

The Crop Insurance Evaluation Program is available in LOTUS 1-2-3 and SuperCalc versions for IBM compatible microcomputers. The spreadsheets each require 256K of random access memory.

## THE COMMODITY PROGRAM ANALYZER

Like the VPI Crop Insurance Evaluation Model, the Commodity Program Analyzer consists of a number of electronic spreadsheets. Each spreadsheet evaluates participation in one of the commodity programs of the 1985 Farm Bill. Whole farm analysis is not facilitated.

Commodity program participation strategies on up to five different operating units can be evaluated in each spreadsheet. This is done because (a) many producers have more than one Agricultural Stabilization and Conservation Service (ASCS) farm number and can choose different participation alternatives on each of these units and (b) the $50,000 and $200,000 per person payment limits apply across these units.

The model permits a producer of a single program crop on multiple units (for farm program purposes) to analyze alternative participation scenarios, fully accounting for the effects of the payment limits. For instance, a grain sorghum producer with five different ASCS farm numbers can analyze scenarios involving alternative ways of participating on each farm. Based on elicited grain sorghum yield and price distributions, the program estimates returns above variable costs after the payment limits have been imposed. If the producer finds that he/she is likely to exceed the limits, he/she can evaluate other strategies that might increase combined net returns from program payments and crop sales.

Greater complexity arises for a producer of more than one program crop. One approach is to distribute the payment limits across program crops according to crop acreage, program yield and expected deficiency payment rates. Each crop is then analyzed separately, across all units. If, under a given scenario, the allocated payment limits take effect on one crop but not on another, a first solution is to simply reallocate the limits. However, if the allocated limits appear likely to be exceeded on all crops, it may be desirable to choose a different participation strategy. This might reduce the likelihood of exceeding payment limits and increase net returns.

Figure 7 is the screen where yield information is entered for a grain sorghum enterprise which will be used as an example. The user assesses five percentiles of the yield distribution. These assessments are conditioned on the assumption that 100% of base acreage is planted. In a second screen (not shown) the user is allowed to shift the median of the assessed distribution to account for the effects of planting reductions associated with various participation options. This procedure assumes that the shape of the distribution is not affected by reduced planting.

Price distributions are elicited using the same format as in figure 7. Yields and prices are assumed to be independent. Expected deficiency payment rates are conditioned on market prices corresponding to the five assessed percentiles of the price distribution. General information, including costs, farm program yield, etc. for the crop on that farm unit are entered on other screens.

Figure 7. Yield Distribution Assessment Screen of Commodity Program Analyzer

ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR 1987 GRAIN SORGHUM YIELD EXPECTATIONS ASSUMING THAT YOU PLANT 100% OF YOUR BASE ACREAGE

| | | |
|---|---|---|
| What is the level that you believe there is only a 5% (1 in 20) chance of your yield falling below? | 18.0 | CWT/AC |
| What is the level that you believe there is only a 25% (1 in 4) chance of your yield falling below? | 22.0 | CWT/AC |
| What is the level that you believe there is an equal chance of your yield either falling below or exceeding? | 30.0 | CWT/AC |
| What is the level that you believe there is only a 25% (1 in 4) chance of your yield exceeding? | 40.0 | CWT/AC |
| What is the level that you believe there is only a 5% (1 in 20) chance of your yield exceeding? | 55.0 | CWT/AC |

After all data have been entered for a crop on one farm unit, calculations are performed (the Appendix provides an example of the calculation procedure) and results are presented in the screens shown in figures 8 and 9. Figure 8 shows five percentiles of the net returns distribution for each of five policy options:

(a) nonparticipation,

(b) planting 80% of base acreage (the maximum permitted),

(c) planting 65% of base acreage under the optional paid diversion,

(d) planting 40% of base acreage under the 50/92 provision, and

(e) planting 32.5% of base acreage under the optional paid diversion and 50/92 provisions.

Mean (expected) returns per acre and mean total deficiency payments are also presented.

The second summary screen (figure 9) shows mean returns per acre for each option as well as mean (expected) deficiency payments subject to the two limits. In this screen the user selects one of the five participation alter natives which are used in the first "multiple unit" analysis.

Figure 8. Enterprise Summary Screen 1 for Commodity Program Analyzer

SUMMARY OF RETURNS PER ACRE UNDER VARIOUS ALTERNATIVES
FOR FARM SORGHUM 1

| % of base planted ------> | | 80% | 65% | 40% | 32.5% |
|---|---|---|---|---|---|
| Percentile | Non-Partic. | Regular Setaside | Optional Diversion | 50/92 Defic. | 50/92 & Optional |
| 0.05 | -37.55 | 24.02 | 39.66 | 26.27 | 35.30 |
| 0.25 | -29.00 | 29.09 | 43.78 | 29.72 | 38.10 |
| 0.50 | -7.76 | 44.30 | 56.15 | 37.33 | 44.29 |
| 0.75 | 30.50 | 71.42 | 78.71 | 49.86 | 54.47 |
| 0.95 | 74.25 | 117.85 | 115.90 | 74.10 | 74.16 |
| Mean Returns/Acre | 9.63 | 61.70 | 70.45 | 45.61 | 51.01 |
| Mean Total Defic. | ----- | 48,642 | 56,302 | 44,751 | 53,140 |
| Option | (0) | (1) | (2) | (3) | (4) |

Figure 9. Enterprise Summary Screen 2 for Commodity Program Analyzer

| Alternative | Option | Mean Returns Per Acre | Mean Defic. Subj. to 50K Limit | Mean Defic. Subj. to 200K Limit |
|---|---|---|---|---|
| Nonparticipation | 0 | 9.63 | ----- | ----- |
| 80% Full Participation | 1 | 61.70 | 33,264 | 15,378 |
| 65% Partic. w/ Opt. Div. | 2 | 70.45 | 43,808 | 12,495 |
| 40% Partic. w/ 50/92 Def. | 3 | 45.61 | 30,603 | 14,148 |
| 32.5% w/ 50/92 Def & Opt. | 4 | 51.01 | 41,645 | 11,495 |

<====== PLEASE SELECT PREFERRED OPTION (0-4)

When data have been entered and policy options chosen for all farm units the results are transferred to a summary section which analyzes grain sorghum results for all farm units. Results of the whole-farm grain sorghum analysis are shown in figure 10. Data for grain sorghum on a second farm unit have been entered to demonstrate the summary procedure. The upper section gives percentiles of the per acre net returns distribution for each farm unit before reductions for deficiency payment limits are made. The lower section gives results after payment limits are imposed. Under the selected policy options (65% planting under the additional paid diversion for both farm units) the reductions are substantial. The proportionate reductions are larger at the lower range of the distributions than at the upper range because the lower range is associated with lower prices and higher deficiency payment rates. Expected mean returns, total returns and total deficiency payments are presented in the screen shown in figure 11.

Figure 10. Commodity Program Analyzer Example Summary Screen 1 for Policy Scenario 1

EXPECTED RETURNS PER ACRE UNDER SCENARIO 1

| FARM | PERCENTILE .05 | .25 | .50 | .75 | .95 |
|---|---|---|---|---|---|
| Before Reduction | | | | | |
| 1. SORGHUM 1 | 40.71 | 45.17 | 58.58 | 78.71 | 106.66 |
| 2. SORGHUM 2 | 40.78 | 47.17 | 63.40 | 84.55 | 112.37 |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |
| After Reduction | | | | | |
| 1. SORGHUM 1 | 25.47 | 29.93 | 43.35 | 63.47 | 91.42 |
| 2. SORGHUM 2 | 25.55 | 31.93 | 48.16 | 69.31 | 97.14 |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |

Figure 11. Commodity Program Analyzer Example Summary Screen 2 for Policy Scenario 1

EXPECTED MEAN RETURNS AND DEFICIENCY PAYMENTS UNDER SCENARIO 1

| FARM | PLANTED ACRES | ALTERNATIVE | MEAN RETURNS PER ACRE | EXPECTED TOTAL RETURNS | EXPECT. TOTAL DEFIC. PAYMENTS |
|---|---|---|---|---|---|
| SORGHUM 1 | 1000 | 65% w/ Opt. Div. | 70.45 | 70,454 | 56,302 |
| SORGHUM 2 | 750 | 65% w/ Opt. Div. | 75.08 | 56,307 | 42,227 |
| TOTALS BEFORE REDUCTION -----------------> | | | | 126,761 | 98,529 |
| SORGHUM 1 | 1000 | 65% w/ Opt. Div. | 55.22 | 55,218 | 41,066 |
| SORGHUM 2 | 750 | 65% w/ Opt. Div. | 59.84 | 44,880 | 30,800 |
| TOTALS AFTER REDUCTION ------------------> | | | | 100,098 | 71,866 |

After one policy participation scenario has been evaluated, the user can return to a menu which permits specification of other policy options. In the example the policy option for farm unit 1 is changed from 65% planting with additional paid diversion, to 80% planting. Figure 12 shows the results for this scenario. All percentiles of the "before reduction" returns distribution for unit 1 are lower than they were under scenario 1 (figure 11). However, the 75th percentile of the "after-reduction" returns distribution for unit 1 is almost equal under the two scenarios and the 95th percentile is larger under scenario 2. Importantly, percentiles of the "after reduction" net returns distribution for farm unit 2 are greater throughout under scenario 2 than for scenario 1.

Figure 13 shows mean returns per acre, total returns and expected total deficiency payments for scenario 2. Comparing these results with those for scenario 1 (figure 11) reveals that expected total returns are greater for scenario 2 than for scenario 1. Thus, as a result of the payment limits, the best policy participation strategy may not be that which appears superior when farm units are analyzed separately.

The Commodity Program Analyzer is a set of Lotus 1-2-3 spreadsheets for IBM PC compatible microcomputers. Each spreadsheet requires 512K of random access memory.

Figure 12. Commodity Program Analyzer Example Summary Screen 1 for Policy Scenario 2

EXPECTED RETURNS PER ACRE UNDER SCENARIO 2

| | PERCENTILE | | | | |
|---|---|---|---|---|---|
| FARM | .05 | .25 | .50 | .75 | .95 |
| Before Reduction | | | | | |
| 1. SORGHUM 1 | 24.64 | 30.32 | 46.66 | 71.42 | 105.82 |
| 2. SORGHUM 2 | 40.78 | 47.17 | 63.40 | 84.55 | 112.37 |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |
| After Reduction | | | | | |
| 1. SORGHUM 1 | 16.53 | 22.21 | 38.55 | 63.31 | 97.71 |
| 2. SORGHUM 2 | 30.10 | 36.49 | 52.72 | 73.87 | 101.69 |
| 3. | | | | | |
| 4. | | | | | |
| 5. | | | | | |

Figure 13. Commodity Program Analyzer Example Summary Screen 2 for Policy Scenario 2

EXPECTED MEAN RETURNS AND DEFICIENCY PAYMENTS UNDER SCENARIO 2

| FARM | PLANTED ACRES | ALTERNATIVE | MEAN RETURNS PER ACRE | EXPECTED TOTAL RETURNS | EXPECT. TOTAL DEFIC. PAYMENTS |
|---|---|---|---|---|---|
| SORGHUM 1 | 1000 | 80% Full Partic. | 61.70 | 61,702 | 48,642 |
| SORGHUM 2 | 750 | 65% w/ Opt. Div. | 75.08 | 56,307 | 42,227 |
| TOTALS BEFORE REDUCTION -----------------> | | | | 118,009 | 90,869 |
| SORGHUM 1 | 1000 | 80% Full Partic. | 53.59 | 53,593 | 40,532 |
| SORGHUM 2 | 750 | 65% w/ Opt. Div. | 64.40 | 48,297 | 34,217 |
| TOTALS AFTER REDUCTION ------------------> | | | | 101,890 | 74,749 |

## DISCUSSION

The four decision aids studied all employ subjective probability elicitation methods that have been used widely in research applications. ARMS and the Commodity Program Analyzer use a variable internal approach (Huber), eliciting assessments of percentiles of each random variable's cumulative distribution. ARMS is the only of the four models which also explicitly accommodates objective or historical probability data. Given its normality assumptions, the elicitation approach of the Risk-Rating Model can also be classified as a variable interval approach, with the elicited values corresponding to the 0.17, 0.5 and 0.83 fractiles of the distribution. The Crop Insurance Evaluation Model employs a fixed interval approach which has been used in numerous research applications (Norris and Kramer).

Outcome summaries for the four models are quite similar. In general, they provide a representation of the outcome distribution along with summary statistics such as means and standard deviations. The Risk-Rating Model also provides estimates of (a) the probability of total returns (receipts) exceeding variable and total cash costs and (b) the probability of a return to equity greater than a user selected rate. The VPI Crop Insurance Evaluation Model provides an estimate of the probability of a loss. Outcomes are summarized on a total unit (enterprise or farm) basis in the Risk-Rating Model and ARMS, while the Commodity Program Analyzer provides estimates of both per acre and total returns. The VPI Crop Insurance Evaluation Model summarizes outcomes on a per acre basis.

The Risk-Rating Model and ARMS accommodate whole farm analysis, whereas the other models do not. Outcomes of such whole farm decisions are functions of several interrelated random variables. The nature of the interrelationships among these variables may be as important as the shapes of the individual marginal distributions. Both the Risk-Rating Model and ARMS incorporate these interrelationships into the analysis using correlation coefficients directly assessed by the decision maker. However, there is an absence of research examining the ability of decision makers to provide such assessments. This emerges as, perhaps, the most important research aim which could contribute to more effective delivery of models for decision making under uncertainty.

Indirect derivation is the method that we believe has most potential for use in obtaining reliable subjective correlation estimates. The questioning procedure would presumably condition assessed values of one variable on specified values of other variables. Such a procedure would have to be carefully developed in order to obtain the necessary information without becoming overly burdensome for the decision maker. Visual references might be useful in the process. We, clearly, do not have the solution to the problem but would encourage others to become involved in investigating the issue.

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## APPENDIX

The implementation of uncertainty analysis in LOTUS 1-2-3 as done in the Commodity Program Analyzer requires some explanation. In this appendix we develop a small example, its LOTUS implementation and the associated explanation. The best way to explain the technique is to demonstrate it. The setting in which we demonstrate it is a simple budgeting and crop planning exercise.

Suppose we wish to compare two acreage plans involving two crops. A basic analytical framework for this would involve consideration of prices, yields, costs, and acreages as in figure 1. Such a framework is easily entered into spreadsheets such as LOTUS 1-2-3. Here the prices, yields, costs and acreages are entered, total revenue and net income are calculated, and then the income for each cropping plan is derived.

Now, suppose that we wish to enter uncertain scenarios for prices and yields. Suppose that historical data show that 10 alternative price-yield combinations for the two crops are as given in figure 2. The question then becomes how do we incorporate such information into a spreadsheet model. This is done in our LOTUS 1-2-3 work using the Table Lookup and Data Table features[1]. Specifically, the LOTUS Data Table command automates spreadsheet recalculation allowing the user to specify multiple values for a parameter with the spreadsheet run once for each parameter value. Our data, however, indicate 4 parameters are to be varied. Accommodation of these four is done through the Table Lookup feature. Specifically, we define a cell (B20 in our example) as the scenario number and then give Lookup functions which extract the proper data values from the uncertain parameters associated with the scenario number specified. Thus, we enter our data in columns H through L, rows 7 through 16, with the scenario number entered in H and the prices and yields in I through L (figure 3). The Lookup functions and the rest of the spreadsheet calculations are as given in figure 4 where @VLookup is a LOTUS function which looks in the data in column H for the scenario number contained in cell B20, then extracts the number from the adjacent columns using a column displacement. Thus, by changing the B20 number from 1 to 2, we would look at Scenario Number 2. The Data Table allows automation of this process. Suppose we wish to run scenarios 1 through 10, recording net income for each plan. The data table is set up as follows (figure 5):

a) Enter a column of numbers representing the scenario numbers you wish to run (Column O). These values correspond to the values entered in the first column (H) of the data lookup table.

b) In the next two columns (P and Q), place the formulas or cell references of the cells containing the total income formulas. Note that these are entered one row above the first scenario number.

c) Issue the data table command, specifying a one-way data table with range O9 to Q18 and designating B20 as the input cell.

The results of each of the 10 scenarios are shown in figure 6.

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1/ This could also be done in SUPERCALC using its Lookup functions, but the data table procedure would need to be emulated through a macro.

The above discussion illustrates the basic method. We have in various applications attached non-uniform probabilities, and caused scenarios to be randomly selected. We have also graphed PDF's and CDF's as well as calculated means, variances, frequency PDF's and confidence intervals from the results in the Data Table.

APPENDIX FIGURE 1. BASIC ANALYTICAL FRAMEWORK

| | CROP 1 | CROP 2 |
|---|---|---|
| Cropname -----> | Sorghum | Corn |
| Price | 3.00 | 2.50 |
| Yield | 30.00 | 95.00 |
| TOTAL REVENUE | 90.00 | 237.50 |
| Expenses | 50.00 | 75.00 |
| NET INCOME | 40.00 | 162.50 |
| Acres Plan 1 | 100 | 50 |
| Acres Plan 2 | 50 | 100 |
| TOTAL INCOME | | |
| PLAN 1 --------> | | 12,125 |
| PLAN 2 --------> | | 18,250 |
| SCENARIO | 1 | |

APPENDIX FIGURE 2. ALTERNATIVE PRICE AND YIELD COMBINATIONS

| | SORGHUM | | CORN | |
|---|---|---|---|---|
| SCENARIO | PRICE | YIELD | PRICE | YIELD |
| 1 | 3.00 | 30.0 | 2.50 | 95.00 |
| 2 | 3.00 | 35.0 | 2.50 | 100.00 |
| 3 | 3.50 | 30.0 | 2.50 | 95.00 |
| 4 | 3.30 | 40.0 | 2.15 | 125.00 |
| 5 | 3.30 | 40.0 | 2.25 | 100.00 |
| 6 | 3.50 | 40.0 | 2.00 | 100.00 |
| 7 | 3.25 | 35.0 | 2.10 | 80.00 |
| 8 | 3.25 | 35.0 | 2.50 | 80.00 |
| 9 | 3.00 | 45.0 | 2.50 | 80.00 |
| 10 | 3.10 | 45.0 | 2.30 | 85.00 |

APPENDIX FIGURE 3. SCENARIO DATA AS ENTERED

COLUMN

| ROW | | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|
| | 1 | | | | | | |
| | 2 | | | | | | |
| | 3 | | | | | | |
| | 4 | | SORGHUM | | CORN | | |
| | 5 | SCENARIO | PRICE | YIELD | PRICE | YIELD | |
| | 6 | | | | | | |
| | 7 | 1 | 3.00 | 30.0 | 2.50 | 95.00 | |
| | 8 | 2 | 3.00 | 35.0 | 2.50 | 100.00 | |
| R | 9 | 3 | 3.50 | 30.0 | 2.50 | 95.00 | |
| O | 10 | 4 | 3.30 | 40.0 | 2.15 | 125.00 | |
| W | 11 | 5 | 3.30 | 40.0 | 2.25 | 100.00 | |
| | 12 | 6 | 3.50 | 40.0 | 2.00 | 100.00 | |
| | 13 | 7 | 3.25 | 35.0 | 2.10 | 80.00 | |
| | 14 | 8 | 3.25 | 35.0 | 2.50 | 80.00 | |
| | 15 | 9 | 3.00 | 45.0 | 2.50 | 80.00 | |
| | 16 | 10 | 3.10 | 45.0 | 2.30 | 85.00 | |
| | 17 | | | | | | |
| | 18 | | | | | | |
| | 19 | | | | | | |
| | 20 | | | | | | |

APPENDIX FIGURE 4. SPREADSHEET FORMULAS

COLUMN

| ROW | | A | B | C |
|---|---|---|---|---|
| | 1 | | CROP 1 | CROP 2 |
| | 2 | Cropname -----> | Sorghum | Corn |
| | 3 | | | |
| | 4 | Price | @VLOOKUP(B20,H7..L16,1) | @VLOOKUP(B20,H7..L16,3) |
| | 5 | Yield | @VLOOKUP(B20,H7..L16,2) | @VLOOKUP(B20,H7..L16,4) |
| | 6 | | | |
| | 7 | TOTAL REVENUE | (B4*B5) | (C4*C5) |
| | 8 | | | |
| R | 9 | Expenses | 50 | 75 |
| O | 10 | | | |
| W | 11 | NET INCOME | (B7-B9) | (C7-C9) |
| | 12 | | | |
| | 13 | Acres Plan 1 | 100 | 50 |
| | 14 | Acres Plan 2 | 50 | 100 |
| | 15 | | | |
| | 16 | TOTAL INCOME | | |
| | 17 | PLAN 1 --------> | | (B11*B13)+(C11*C13) |
| | 18 | PLAN 2 --------> | | (B11*B14)+(C11*C14) |
| | 19 | | | |
| | 20 | SCENARIO | 1 | |

APPENDIX FIGURE 5. DATA TABLE BEFORE CALCULATION

| | O | P | Q | R |
|---|---|---|---|---|
| 5 | | | | |
| 6 | | DATA TABLE | | |
| 7 | | | | |
| 8 | | +C17 | +C18 | |
| 9 | 1 | | | |
| 10 | 2 | | | |
| 11 | 3 | | | |
| 12 | 4 | | | |
| 13 | 5 | | | |
| 14 | 6 | | | |
| 15 | 7 | | | |
| 16 | 8 | | | |
| 17 | 9 | | | |
| 18 | 10 | | | |
| 19 | | | | |
| 20 | | | | |

APPENDIX FIGURE 6. DATA TABLE AFTER CALCULATION

| | O | P | Q | R |
|---|---|---|---|---|
| 5 | | | | |
| 6 | | DATA TABLE | | |
| 7 | | | | |
| 8 | | +C17 | +C18 | |
| 9 | 1 | 12,125 | 18,250 | |
| 10 | 2 | 14,250 | 20,250 | |
| 11 | 3 | 13,625 | 19,000 | |
| 12 | 4 | 17,888 | 23,475 | |
| 13 | 5 | 15,700 | 19,100 | |
| 14 | 6 | 15,250 | 17,000 | |
| 15 | 7 | 11,025 | 12,488 | |
| 16 | 8 | 12,625 | 15,688 | |
| 17 | 9 | 14,750 | 16,750 | |
| 18 | 10 | 14,975 | 16,525 | |
| 19 | | | | |
| 20 | | | | |