THE AGRICULTURAL RISK MANAGEMENT SIMULATOR MICROCOMPUTER PROGRAM

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Abstract

The Agricultural Risk Management Simulator (ARMS) is a microcomputer program designed to help users evaluate strategies for managing yield and price risk in crop farming operations. Risk management strategies are defined by choices regarding crop mix, the purchase of multiple peril crop insurance, and the use of forward contracting. Probabilistic budgeting is used to determine the net cash flow probability distribution for each strategy considered. Flexibility with regard to both sources of probabilistic information and the form of yield and price probability distributions is a noteworthy feature of the program.

Key words: risk management, simulation, probabilistic budgeting, crop insurance.

The Agricultural Risk Management Simulator (ARMS) is a microcomputer program that helps users evaluate strategies for managing yield and price risk in crop farming operations. ARMS analyzes how annual net cash flow probability distributions are affected by three important risk management mechanisms: changes in crop mix, the purchase of multiple peril crop insurance, and the use of forward contracting.

ARMS is designed for use in teaching risk management concepts to students, farmers, and farm management advisors. It is also a tool that farmers, lenders, and farm management advisors can use for farm planning. Additionally, for agricultural software developers, ARMS illustrates a general framework for analysis, probabilistic budgeting, that can be used in other risk management applications.

CONCEPTUAL FOUNDATIONS

Probabilistic budgeting methods are used in ARMS to evaluate the impact of alternative management strategies on annual net cash flow probability distributions. Probabilistic budgeting is a straightforward extension of the payoff matrix concept (Nelson, Casler, and Walker). Net cash flow is calculated for each management strategy being considered in each of a large number of sample "states of nature" drawn from the joint distribution of random factors affecting performance. In ARMS, a state of nature is defined by yield and price levels for each crop enterprise. For each strategy, the budgeted outcomes define the net cash flow distribution.

A probabilistic budgeting model can be decomposed into two relatively independent submodels: (1) a probability submodel that generates sample states of nature and (2) a deterministic simulation submodel that budgets the performance of any allowable management strategy under any possible state of nature. This decomposition makes it possible to consider interactions among random factors and management decisions that would be difficult to model analytically. For example, the effects of risk management instruments such as multiple peril crop insurance and commodity program participation, which establish lower bounds on yields or prices, cause problems in analytical models because they tend to truncate net return distributions. The effects of such instruments can easily be represented with "if...then" statements in a deterministic simulation submodel, and their impact on outcome distributions can be explored by budgeting the performance of strategies that use them in many states of nature generated by a pro-

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bability submodel. This decomposition also reduces the need for restrictions on the form of probability distributions, restrictions that must often be imposed in analytical models to allow explicit representation of relationships among random factors, management decisions, and outcome distributions.

The probability submodel in ARMS generates sample yield and price levels from a user-specified joint distribution of yields and prices for up to four crop enterprises. It allows considerable flexibility in both the source of probabilistic information and the form of probability distributions. The generalized multivariate process generator developed by King (1979) is the central component of this submodel. It generates sample vectors from multivariate distributions defined by a cumulative distribution function (CDF) for each marginal distribution and a correlation matrix. It places no restrictions on the form of the marginal distributions.

The budgeting submodel in ARMS calculates annual before-tax net cash flow for farm operations with up to four crop enterprises. A detailed description of its structure is presented in the Technical Appendix of the ARMS User Manual (King, 1987). Management strategies are defined by choices regarding crop mix, multiple peril crop insurance coverage, and the use of forward contracting.

DATA REQUIREMENTS

ARMS is divided into three major sections: (1) the Farm and Enterprise Information Section, (2) the Yield and Price Probability Section, and (3) the Strategy Evaluation Section. Within each section, the general flow of data entry and output display is controlled by menus. Error trapping and range checking routines are incorporated into each input screen. Function keys control operations such as displaying HELP screens, moving from one screen to another, editing data, printing results, and displaying graphs. Default data values are not incorporated into the program, but the data entered in each section can be stored for subsequent retrieval and modification.

In the Farm and Enterprise Information Section, the user builds a simple description of the farm operation being analyzed. Crop enterprises to be considered are identified. Preharvest cash production costs, a constant per acre component of cash harvest costs, and a yield-sensitive component of cash harvest costs are specified for each enterprise. Cash overhead expenses and total crop acreage are also specified.

In the Yield and Price Probability Section, the user enters the data required to describe the joint probability distribution of yields and prices. Specific data requirements depend on the data entry options selected by the user for each marginal distribution. A crop yield can be assumed to be nonrandom and set at a constant planning value. Alternatively, its distribution can be represented by an empirical CDF based on historical data; by a truncated normal distribution with user-specified mean, standard deviation, minimum, and maximum; or by a subjective distribution elicited using the judgmental fractile method (Raiffa). A crop price can be set at a constant planning value. If random, its distribution can be represented by a truncated normal distribution, by a subjective CDF, or by a nonparametric CDF derived from commodity option premiums (King and Fackler). For both yields and prices, the user can select the mode of data entry for each marginal distribution, facilitating the use of probabilistic information from a range of sources. Regardless of the mode of data entry, the initial CDF representation of each marginal distribution can be modified subjectively by the user.

Users enter correlations between yields after all yield distributions have been defined. Correlations between prices and between yields and prices are entered after all price distributions have been defined. Once the marginal distributions and correlation matrix have been specified, the probability submodel generates up to 250 sample yield and price combinations.

In the Strategy Evaluation Section, the user enters values for parameters that define up to three management strategies. Crop mix decisions are defined by acreage levels for each crop, subject to the user-specified constraint on total acreage. Multiple peril crop insurance coverage is defined by an insurable yield, a percent coverage (50, 65, or 75 percent), a price election, and a premium. This information is available from agents who sell multiple peril crop insurance. Forward contracting decisions are defined by the percent of the expected crop to be contracted and the current forward contract bid.

In each strategy, the enterprise and overhead cost data from the Farm and Enterprise Information Section are used to budget net cash flow for each of the sample yield and

CROP PRODUCTION COSTS				
Crop Name	CORN	SOYBEANS	PEAS	SETASIDE
Production Unit	bu.	bu.	cwt.	bu.
Preharvest Variable Costs ($/ac)	79.71	44.62	56.00	15.00
Harvest Costs: Per Acre Component ($/ac)	17.69	9.92	0.00	0.00
Harvest Costs: Per Unit Component ($/unit)	0.40	0.07	0.00	0.00

FARM SIZE AND OVERHEAD EXPENSES	
Total Tillable Acres:	600
Total Overhead Expenses:	74700.00

Figure 1: Farm and Enterprise Information: Case Farm Analysis.

YIELD CUMULATIVE DISTRIBUTIONS				
	CORN	SOYBEANS	PEAS	SETASIDE
Minimum	40.00	20.00	5.50	480.00
1st Percentile	47.56	21.40	16.36	480.00
5th Percentile	61.60	24.33	19.77	480.00
10th Percentile	74.20	27.44	21.59	480.00
20th Percentile	88.60	31.58	23.79	480.00
40th Percentile	107.60	37.76	26.73	480.00
50th Percentile	115.60	39.76	28.00	480.00
60th Percentile	123.60	41.54	29.27	480.00
80th Percentile	140.54	45.29	32.21	480.00
90th Percentile	150.13	47.75	34.41	480.00
95th Percentile	153.56	49.89	36.23	480.00
99th Percentile	156.31	50.79	39.64	480.00
Maximum	157.00	51.00	40.00	480.00
Mean	113.39	38.67	27.99	480.00
Std. Deviation	27.95	7.46	4.94	0.00
Coef. of Var.	0.25	0.19	0.18	0.00
Coef. of Skew.	-0.24	-0.44	-0.01	0.00

Figure 2: Yield Distributions: Case Farm Analysis.

price combinations generated in the Yield and Price Probability Section. The resulting set of net cash flows defines the strategy's net cash flow distribution. Though only three strategies can be evaluated at a time, the user can modify strategies after the results of each probabilistic budgeting analysis are displayed. Through multiple runs, then, an essentially unlimited number of strategies can be evaluated under the same enterprise and overhead cost and yield and price probability assumptions.

PRICE CUMULATIVE DISTRIBUTIONS				
	CORN	SOYBEANS	PEAS	SETASIDE
Minimum	1.70	4.67	7.00	0.00
1st Percentile	1.70	4.67	7.00	0.50
5th Percentile	1.70	4.67	7.00	0.60
10th Percentile	1.70	4.67	7.00	0.70
20th Percentile	1.70	4.67	7.00	0.81
40th Percentile	1.72	4.69	7.00	0.90
50th Percentile	1.75	4.76	7.00	0.92
60th Percentile	1.86	4.88	7.00	0.95
80th Percentile	2.05	5.41	7.00	0.97
90th Percentile	2.15	5.76	7.00	0.97
95th Percentile	2.27	5.95	7.00	1.00
99th Percentile	2.34	6.20	7.00	1.02
Maximum	2.40	6.40	7.00	1.03
Mean	1.86	5.00	7.00	0.88
Std. Deviation	0.19	0.44	0.00	0.13
Coef. of Var.	0.10	0.09	0.00	0.15
Coef. of Skew.	1.73	1.63	0.00	-0.92

Figure 3: Price Distributions: Case Farm Analysis.

CORRELATION MATRIX DATA

Crop Number	Yield / Yield 1	2	3	4	Yield / Price 1	2	3	4
1	1.000	0.760	0.100	0.000	0.000	0.000	0.000	0.000
2	0.760	1.000	0.250	0.000	0.000	0.000	0.000	0.000
3	0.100	0.250	1.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000

Crop Number	Price / Yield 1	2	3	4	Price / Price 1	2	3	4
1	0.000	0.000	0.000	0.000	1.000	0.790	0.000	-0.950
2	0.000	0.000	0.000	0.000	0.790	1.000	0.000	-0.700
3	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
4	0.000	0.000	0.000	0.000	-0.950	-0.700	0.000	1.000

KEY

Crop Number	Crop Name	Crop Number	Crop Name
1	CORN	3	PEAS
2	SOYBEANS	4	SETASIDE

Figure 4: Correlation Matrix: Case Farm Analysis.

RESULTS FROM A CASE FARM ANALYSIS

The output from ARMS can be illustrated by presenting the results of a case farm analysis. Sources of data, data entry, and the interpretation of output results for this case are discussed in greater detail in the user manual (King, 1987).

The case farm is a 600-acre cash crop operation in southeastern Minnesota. All land is owned, and expansion through land purchase or rental is not being considered. Corn and

STRATEGY SPECIFICATION			
Crop Acreage	Strategy 1	Strategy 2	Strategy 3
CORN	240	240	240
SOYBEANS	300	300	200
PEAS	0	0	100
SETASIDE	60	60	60
Crop Insurance	(Percent Coverage and Price Election)		
CORN	0% $ 0.00	65% $ 2.00	0% $ 0.00
SOYBEANS	0% $ 0.00	65% $ 4.00	0% $ 0.00
PEAS	0% $ 0.00	0% $ 0.00	0% $ 0.00
SETASIDE	0% $ 0.00	0% $ 0.00	0% $ 0.00
Forward Contracting	(Percent Contracted and Contract Price)		
CORN	0% $ 0.00	0% $ 0.00	0% $ 0.00
SOYBEANS	0% $ 0.00	40% $ 4.99	0% $ 0.00
PEAS	0% $ 0.00	0% $ 0.00	0% $ 0.00
SETASIDE	0% $ 0.00	0% $ 0.00	0% $ 0.00

Figure 5: Strategy Summaries: Case Farm Analysis.

NET CASH FLOW CUMULATIVE DISTRIBUTIONS ($/year)			
	Strategy 1	Strategy 2	Strategy 3
Minimum	-36924	-28411	-30644
1st Percentile	-35740	-25927	-29013
5th Percentile	-31969	-24359	-24211
10th Percentile	-23077	-20787	-17374
25th Percentile	-7198	-9171	-4603
40th Percentile	2560	503	3560
50th Percentile	7186	5895	8090
60th Percentile	12161	10296	11260
75th Percentile	21299	17944	20046
90th Percentile	33207	30158	31537
95th Percentile	39814	35200	36723
99th Percentile	49749	43055	42418
Maximum	55927	48505	47151
Mean	6801	5361	7583
Std. Deviation	20496	18033	17705

Figure 6: Net Cash Flow Distributions: Case farm Analysis.

soybeans are the major crop enterprises for the farm, and there is an opportunity to add sweet peas for processing as a new enterprise. The time is early March 1986, and final plans are being made for the 1986 crop year. The operator wants to evaluate the impact of adding peas to his crop mix. He also wants to make decisions about the purchase of multiple peril crop insurance and about contracting some of his corn and soybean production for harvest delivery. He has already decided to participate in the government program for corn. Since this requires a 20 percent acreage reduction, a fourth enterprise, setaside, has been added to the analysis. The enterprise cost, overhead cost, and acreage data entered for this operation in the Farm and Enterprise Information Section are summarized in Figure 1. Enterprise costs for corn, soybeans, and setaside are based on budgets distributed by the Minnesota Extension Service (Benson and Gensmer). Costs for peas are based on a processor's estimates. Harvest costs for peas are zero because peas are harvested by the processor.

Yield distributions for the case farm analysis are represented by the tabular CDFs in Figure 2. The corn and soybean yield distributions are based on historical data for the case farm. The yield distribution for peas is a truncated normal distribution. Its mean, standard deviation, minimum, and maximum are based on subjective estimates provided by a processor. The "yield" for setaside acres is a constant: the number of bushels on which deficiency payments will be made for each acre of setaside. Since 20 percent of corn acreage is setaside, deficiency payments are made on four acres for every acre of setaside. The "yield" for setaside, then, is 480 bushels per acre, four times the farm's ASCS established yield of 120 bushels per acre.

Price distributions for the case farm are shown in Figure 3. The corn and soybean distributions are derived from futures option premiums quoted on March 11, 1986. They have been adjusted for the local basis and are probabilistic forecasts of the cash price at harvest. Both have been truncated at the loan rate on the lower end to reflect commodity program participation. Peas have a constant price quoted by the processor for all production on contracted acreage. The "price" distribution for setaside acres is a subjective assessment of the probability distribution for deficiency payments. This was made by an extension marketing specialist in early March 1986.

The correlation matrix for the joint yield and price distribution is summarized in Figure 4. Because correlation estimates based on small samples are unreliable, the yield correlations are based on correlation coefficients for 25 years of detrended county average yields from each of several counties surrounding that of the case farm. The price correlations are based on correlation coefficients for deflated state average prices for major crops in Minnesota and on direct subjective estimates of correlations among deficiency payments and corn and soybean prices made by an extension marketing specialist. All yield/price correlations are assumed to be zero. This assumption is reasonable, given the relatively minor effect yield fluctuations in the area around the case farm would have on world corn and soybean supply levels, especially at a time when stocks worldwide were at unusually high levels.

The three risk management strategies considered in this analysis are summarized in Figure 5. Corn and setaside acreage are identical in all three, reflecting full participation in the corn program with a corn base of 300 acres. The remaining acreage is planted in soybeans in Strategies 1 and 2. In Strategy 3, 200 acres are planted in soybeans, and 100 acres are planted in peas. This is, then, a more diversified strategy. Multiple peril crop insurance and forward contracting are not used in Strategies 1 and 3. Crop insurance is purchased for corn and soybeans at the 65 percent coverage level in Strategy 2, and 40 percent of the expected soybean crop is forward contracted for harvest delivery at a price of $4.99 per bushel. Forward contracting of corn is excluded from all three strategies because the forward contract bid for harvest delivery, $1.77 per bushel, is well below the expected corn price and only a few cents above the loan rate.

The net cash flow distributions for these three strategies are represented by the tabular CDFs in Figure 6. These are based on budgeted net cash flow levels for each strategy in each of 250 sample yield/price combinations drawn from the joint distribution defined in Figures 2, 3, and 4. The cost assumptions are those summarized in Figure 1. In this case, Strategy 1 can be considered a base strategy, since it minimizes the use of risk management tools. Adding multiple peril crop insurance and limited use of forward contracting in Strategy 2 reduces downside risk considerably and lowers expected net cash flow only slightly. In Strategy 3, substituting peas for 100 acres of soybeans is the only change from the base strategy. This increases expected net cash flow slightly and reduces downside risk by improving cash flow levels through the 50th percentile. Except at very low and high percentile levels, the net cash flow distribution for Strategy 3 is also more attractive than that for Strategy 2. Among these strategies, all but very risk-loving and very risk-averse decision makers would be expected to prefer Strategy 3. Highly risk-averse decision makers would prefer Strategy 2 because it reduces maximum losses, while highly risk-loving decision makers would prefer Strategy 1 because it increases maximum gains. The effectiveness of crop insurance in reducing catastrophic losses in Strategy 2 suggests it may be worthwhile to evaluate the performance of additional strategies that include peas and the use of multiple peril crop insurance.

FIELD TESTING

ARMS has been field tested in a series of training workshops with Minnesota county extension agents. On a 5-point scale, with a rating of 1 for poor and 5 for excellent, the 34 agents completing the workshops rated the program 4.02 for its usefulness as a decision aid, 4.26 for its usefulness in self-education and evaluation, and 4.19 for its usefulness in constructing benchmark farm analyses for use in their own extension programs. They expressed concern about using the program directly with farmers without further training, rating the program's usefulness in this area 3.42 on the same 5-point scale. The county agents suggested that the program was paticularly well suited for use by loan officers and farm management consultants.

HARDWARE REQUIREMENTS AND AVAILABILITY

ARMS can be run on IBM PC, XT, and AT (or compatible) microcomputers using MS-DOS or PC-DOS version 2.0 or higher. A minimum of 256K of random access memory and two floppy disk drives or a floppy disk drive and a hard disk are required to run the program. Users with an optional graphics monitor and adapter can display graphical representations of yield, price, and net cash flow distributions.

ARMS is distributed with a user manual and case farm data disk by the Minnesota Extension Service. The regular price for this package is $30 per copy. Extension personnel and those qualifying for a quantity discount are charged $15 per copy.

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