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A General Simulation Model for Farm Firms

By H. R. Hinman and R. F. Hutton

A generally accepted theory of firm behavior is incorporated into an abstract computerized simulation model capable of handling many different environments and organizations. This model provides a means of studying management problems using the simulation approach by providing, in most instances, only data needed to describe the problem situation. For cases in which the situation to be studied is different from the general logic of the model, link points are provided at which the basic logic of the model can be modified.

Key words: Farm firms, firm behavior, simulation, farm management, methodology.

Computer simulation has been widely accepted by agricultural economists.[1] However, one of the problems encountered in applications has been the time and expense involved in preparing computer programs to represent the environment and organization being studied. The model reported in this paper incorporates the generally accepted theory of firm behavior into an abstract computerized simulation model capable of handling many different farming environments and organizations. In addition, it provides convenient link points at which the basic logic can be modified. The object is to provide a means of studying management problems using the simulation approach by providing, in most instances, only the data needed to describe the problem situation. The definition of the problem at the level of data input eliminates or greatly reduces the need to develop computer programs specific to each problem.

All numeric coefficients and all activity, product, and input service identifications are entered as data. Physical resources controlled by the firm are described in terms of the type of input service they render, their quantity, and, if they are depreciable, their age. Production opportunities are described in terms of input services rendered and outputs produced. Output of each product may be treated as a probability event and, subject to modifications, may be considered to reflect alternative rates of efficiency.

The model permits expression of alternative sets of technical relationships for given enterprises and for alternative sets of enterprises. It allows expression of variability in crop and livestock production due to natural hazards—weather, plant or animal diseases, insect damage, ill health of the operator or his laborers, and other like sources of risk in farming. It also permits variability in product prices and allows expression of trend over time in product prices and in the value of assets. A full description of the features, logic, and instruction as to the use of this simulation model is contained in "A General Agricultural Firm Simulator."[2] The general theory and logic incorporated into this simulator are discussed in the following sections.

Characteristics

The general simulator is designed to handle any farm situation. Thus, the production alternative, or activities, and the resources, as represented by input services and products, are entered as technical coefficients relating input to product, costs and prices. The flow of operations performed by the general simulator follows that outlined by the solid lines of figure 1. The dashed lines represent modifications that are discussed later.

[1] E. M. Babb and L. M. Eisgruber. Management Games for Teaching and Research, Ed. Methods, Inc., 1966.

L. M. Eisgruber. Farm Operation Simulator and Farm Management Game, Res Prog. Rpt. 162, Ind. Agr. Expt. Sta., Lafayette, Feb. 1965.

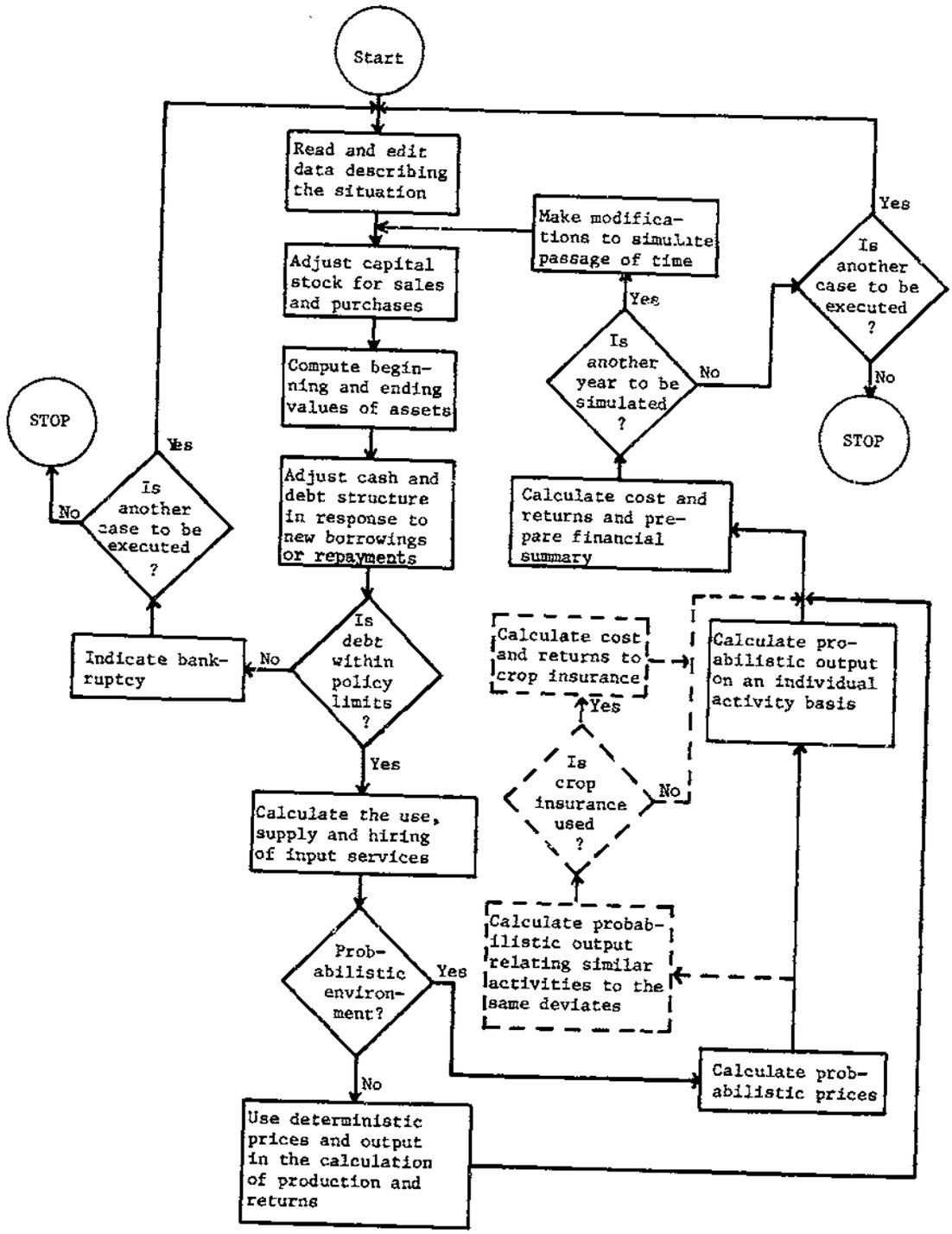
A. N. Halter and G. S. Dean. Simulation of a California Range-Feedlot Operation. Calif. Agr. Expt. Sta. Rpt. 282, May 1965.

R. F. Hutton. A Simulation Technique for Making Management Decisions in Dairy Farming. U.S. Dept. Agr., Agr. Econ. Rpt. 87, Feb. 1966.

[2] R. F. Hutton and H. R. Hinman. A General Agricultural Firm Simulator. A.E. & R.S. No. 72, Dept. Agr. Econ. and Rural Soc., Agr. Expt. Sta., Pa. State Univ., May 1968. (Revised July 1969.)

[3] H. R. Hinman. Appraising Results of Alternative Finance Management Practices by Use of Simulation. Unpublished Ph.D. thesis, Pa. State Univ., Dec. 1969.

Flow Chart of General Agricultural Firm Simulator



(Extensions and modifications are indicated by dashed lines and boundaries).

Figure 1

Capital Stock

The input data will identify the initial inventory of capital goods. The capital stock is adjusted for sales and purchases at the start of the year. The prices at which these assets are purchased or sold are specified as data. The prices may, at the option of the user, be subjected to trend values over simulated time and the assets purchased may be subjected to minimum quantity regulations.

Physical capital items owned by the firm are described in terms of the type of input service they provide, their value, and if depreciable, their age. Depreciation of capital is on a straight-line basis. When an item is fully depreciated, it ceases to provide input services. Assets, such as land, that have an infinite life can be identified in the input as nondepreciable. In the calculations of beginning and ending values the assets may be subject to appreciation or depreciation related to monetary inflation or deflation as well as depreciation over simulated time to reflect wear-and-tear and obsolescence.

Debt Structure

The initial financial status of the firm is specified in the input data. The cash balance and debt structure are adjusted each simulated year for any new borrowings or prepayment of debts. Up to three types of credit are provided for within the framework of the model. The terms for the credit are specific to the data presented by the user. For each type of credit the user must specify the type of collateral suitable for use as security, the length of the repayment period and the interest rate. It was anticipated in the model design that the three types of credit would be (1) long-term credit that needs real estate as security, (2) intermediate-term credit that needs either real estate or chattel as security, and (3) short-term credit that can use real estate, chattel, and the general standing of the firm as security. However, other alternatives may be used.

Credit of each type may have a minimum percentage of collateral required. If the security required for the debt cannot be met, after any relevant refinancing the farm is forced into simulated bankruptcy. If the debt structure is within the limits set by the policy governing debt management, the supply, use, and hiring of input services for the year are calculated.

Inputs

Input services required for the operation of the firm are provided by capital owned or controlled by the firm, by direct service purchases (renting), or by products of current production. The capital goods in inventory are considered first as a source of input services. Next in order as sources of inputs are the intermediate products, such as feed, produced during the year. Needed inputs not obtained from either of these sources are purchased on the open market. These purchases may be subject to minimum lot sizes and the purchase price may be subject to price trends. Unused services provided by physical capital can be left idle or sold directly. Intermediate products remaining after input demands have been satisfied may be sold on the open market or placed in inventory. Intermediate products in inventory may be used the following year as collateral for loans. In the following year these intermediate products may be sold, used to satisfy input needs, or allowed to remain in inventory.

Price and Yield

One of the options in the model permits prices and yields to be selected on a probabilistic basis. In the probabilistic calculation of yield, the average yield per unit, the standard deviation of yield, and the limits within which yield is allowed to vary must be specified.

For each product of each activity, a random deviate is drawn without replacement from a population with a mean of zero and a standard deviation of one. This deviate specifies the direction and extent of variation in yield from the average. If the selected deviate is outside the limit of variation specified by the input data, it is rejected and another is selected. If the selected deviate is satisfactory, the product of it and the standard deviation is added to the average output to obtain the base yield. This base yield is then adjusted to account for departure of management efficiency from the basic level to obtain the yield per unit for the year.

For example, assume that the simulator is at the point of selecting a year's yield of alfalfa hay. The user has specified that the average production of alfalfa is 3 tons, the standard deviation is .90, and production is not allowed to vary more than two standard deviations. The model selects a factor from a population with a normal distribution, having a mean zero and standard deviation of one, to determine the number of standard deviations yield departs from the average. If the factor selected is outside the range of -2 to 2, it is rejected and another is selected. Assume, however, that the factor selected is -.95. The deviation from average yield is calculated as follows:

Standard deviation	X	Random deviate	=	Deviation
.90	X	-.95	=	-.855 ton

The base yield per acre of alfalfa grown for the year is: 3 tons -.855 ton = 2.145 tons.

The base yield is subjected to the management efficiency adjustment specified in terms of percentage of yield, to determine the yield per acre of alfalfa grown for the year. For example, if the factor specified that this farmer's efficiency was 90 percent of standard, yield per acre for the year would be: 2.145 X .90 = 1.9341 tons.

If the deterministic mode of simulation is used, the yield per unit for the simulated activity is determined by multiplying the efficiency factor by the average product per unit. This would be the same as the above treatment if the random deviate was always zero.

Probabilistic prices are chosen in a manner similar to that outlined for yield. The user specifies the average price, standard deviation, and limit to variation. The average price may be adjusted for trend. If a trend adjustment is made, the standard deviation is also adjusted to maintain the original ratio of price to deviation. A random deviate is multiplied by the standard deviation and the resulting product is algebraically added to the trend-adjusted average price to obtain the price for the year.

If the deterministic mode of simulation is used, the price per unit of product is determined by adjusting the average price for trend value.

Returns

The returns to the farm are calculated on both a cash and a net income basis. The net income includes gains and losses resulting from asset appreciation and depreciation. Costs included in this calculation and not discussed previously in this paper are the opening and closing costs for loans, property taxes, insurance, direct cash cost related to each activity, and maintenance and repair costs.

Income and social security taxes are levied against the firm's cash income. In the calculation of taxable income, depreciation along with the normal allowances for dependents and the "standard" tax deductions are subtracted from cash income. A withdrawal for family expenditures and the payment of debt principal are made from the firm's cash reserves before the ending financial summary is calculated and the results for the year recorded.

The ending financial summary for a one-year simulation of a farming situation, run first in the deterministic mode and then in the probabilistic mode, is given in the appendix. In the particular instance the deterministic run yielded some $3,000 more net cash income than the probabilistic. After many replications of the probabilistic, the average would be expected to approximate that of the deterministic. However, a series of several replications of the probabilistic will yield information on income variability not available from the deterministic run.

Treatment of Time

If another year of the current situation is to be projected, the simulator makes the modifications needed to characterize passage of time. Prices and asset values will be updated in accordance with their respective trend in value if such trends were indicated by data. The age of each depreciable asset is increased by a year. Additional borrowings, purchases, or sales of capital assets, and change in the organization of the firm's enterprises may remain the same as that of the previous year or be modified for the coming year by one of two methods. One method is to provide data describing the borrowings, purchases, and sales of capital assets and the organization of the firm's enterprises for the coming year. The other method is to use a subroutine, called at the end of each year's run, which simulates the environmental conditions resulting in change in those variables. This subroutine is currently a "user" subroutine that can be designed by the user to reflect the conditions of the particular environment being simulated. This and other "user" subroutines are discussed in the following sections.

If an additional year is not to be projected for the situation, the ending results of this situation will be stored on a history file, and the simulator proceeds to read and edit the data describing another situation if one is offered. In this manner, several versions of similar situations, corresponding to different assumptions regarding either internal management or external environment, can be conveniently explored in a series.

Modification by User Program

The logic of this model is based upon a generally accepted theory of firm behavior. However, different environments or organizations may require a change from this logic or the objectives of an analysis may call for a more comprehensive simulation than that offered

in the general model. To provide for such eventualities without extensive reprogramming, subroutines are called at eight points in the analysis. These points were selected with the intent of providing exits at points where the user could conceivably be expected to offer alternatives to the logic of the general simulator. The subroutines entered at these exits may be written to the user's specifications to modify data to reflect change in logic. All major data arrays are in common storage locations and are easily addressed by such subroutines. The use of these subroutines is unlimited and extremely useful. For example, in a recent study that used this model to appraise alternative financial management practices,[3] subroutining was used in two ways to adapt the general model to the study. These revisions are indicated by the flows outlined by dashes in figure 1 and are described below.

The general model does not relate probabilistic yield of one activity with the probabilistic yield of another activity. In a nonirrigated farming situation, as was used in the above-mentioned study, similar crops grown and harvested during the same period of the year were generally affected in similar fashion by the environmental conditions. Therefore, a subroutine was used to revise the model so that crops grown and harvested during the same period of the year would be subject to the same deviate.

One of the purposes of the study was to evaluate crop insurance under different environmental and equity situations. The general model will not handle cost and returns of crop insurance; therefore, a special subroutine was used to modify the simulator to accommodate the analysis. Both of these changes were accomplished in less than 60 FORTRAN statements. This was a minor undertaking compared to the 1,600 executable statements in the main body of the simulation program.

One of the exits from the main model program to a subroutine is at the end of the writing of the "history" for each period. There is no limit to the variety of things the user can do at this point to reflect change in multiple-period runs. One example is the modification of input or output coefficients over simulated time. Another is the imposition of more complex changes in price or cost rates than the linear trend provided in the model. Still another is a modification that will lead to storage of results, on magnetic tape or a similar device, for use by subroutines to be called later in the analysis. Perhaps the most useful feature is that the simulation model offers an opportunity for incorporating a set of decision rules to carry the situation from one year to the next. In the study previously mentioned, this exit was used to incorporate a very comprehensive set of decision rules into the model. In this way, consequences of alternative decision rules over time could easily be traced.

A call to a subroutine is also made at the end of the simulation of a case. This is either at the expiration of the indicated number of periods or at the completion of the indicated number of replications and number of periods. This exit is useful in processing the results of the simulation just completed by subjecting the information generated in all the runs for the case to statistical or other appropriate analysis. This is also the point at which a "report writing" routine could be used to summarize the results of the analyses.

Appendix: Sample Output

The sets of output in tables 1 to 6 result from a specific farming situation run in both the deterministic and probabilistic modes of the simulator. All output printed is done so at the option of the user. The table headings and footnotes explaining the purpose of the output are not part of the output.

[3] H.R. Hinman. Appraising Results of Alternative Finance Management Practices by Use of Simulation. Unpublished Ph.D. thesis, Pa. State Univ., Dec. 1969.

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Table 1.—Summary of capital transactions and adjustments made in the inventory stock and the borrowing schedules for the year*

1. DETERMINISTIC - CASE 1 1970

CAPITAL CLASS	BOUGHT	SOLD	PRICE	VALUE
TRACTOR		1.0	1400.00	1400.00
COMBINE		1.0	1875.00	1875.00
GEN BARN	1.0		3200.00	3200.00
FEEDERS	10.0		125.00	1250.00
FEEDERS	10.0		124.50	1245.00
FEEDERS	10.0		124.00	1240.00
FEEDERS	10.0		123.50	1235.00
FEEDERS	10.0		123.00	1230.00
FEEDERS	10.0		122.50	1225.00
FEEDERS	10.0		122.00	1220.00
FEEDERS	10.0		121.50	1215.00

1.00 UNITS OF BALER WERE DROPPED FROM INVENTORY
80.00 UNITS OF FEEDERS WERE DROPPED FROM INVENTORY
CASH FELL BELOW MINIMUM LEVEL BY 2785.01
CLASS 1 DEBT EXCEEDS SECURITY VALUE
REDUCE CLASS 1 AND INCREASE CLASS 3 DEBT BY 46.02

*This table is the same for the probabilistic version of this situation and therefore will not be illustrated for the sample probabilistic run.

Table 2.—Supply and use of input services*

1. DETERMINISTIC - CASE 1 1970

INPUT CLASS	SUPPLY	USE	HIRE-IN	HIRE-OUT	$ AMOUNT
TRACTOR	800.00	1139.00	339.00	0.0	1190.00
PLOW	500.00	99.00	0.0	401.00	0.0
MOWER	200.00	37.00	0.0	163.00	0.0
BALER	250.00	37.00	0.0	213.00	0.0
DRILL	100.00	6.80	0.0	93.20	0.0
COMBINE	0.0	14.20	14.70	0.0	90.40
PLANTER	120.00	35.00	0.0	85.00	0.0
PICKER	200.00	47.50	0.0	152.50	0.0
HARVESTER	200.00	30.00	0.0	170.00	0.0
SPREADER	350.00	348.00	0.0	2.00	0.0
BARN DAIRY	20.00	20.00	0.0	0.0	0.0
GEN BARN	2400.00	2000.00	0.0	400.00	0.0
LAND II	60.00	80.00	20.00	0.0	400.00
LAND III	50.00	50.00	0.0	0.0	0.0
LAND VI	40.00	80.00	40.00	0.0	200.00
LABOR 1Q	640.00	1122.00	482.00	0.0	723.00
LABOR 2Q	640.00	1210.00	570.00	0.0	855.00
LABOR 3Q	640.00	1086.00	446.00	0.0	669.00
LABOR 4Q	640.00	992.00	352.00	0.0	528.00
FEED GRAIN	2560.00	2200.40	0.0	359.60	0.0
SUPPLEMENT	0.0	154.00	154.00	0.0	832.50
HAY	408.00	270.00	0.0	138.00	0.0
CASH COST	0.0	10264.00	10264.00	0.0	10264.00
DAIRY COWS	20.00	20.00	0.0	0.0	0.0
HARROW	200.00	30.10	0.0	169.90	0.0
FEEDERS	80.00	80.00	0.0	0.0	0.0

*This table is the same for the probabilistic version of this situation and therefore will not be illustrated for the sample probabilistic run.

Table 3.—Summary of yield per unit, number of production units, total production, and product prices for deterministic version*

1. DETERMINISTIC - CASE 1 1970						
ACTIVITY	PRODUCT	PROD/UNIT	NO. UNITS	TOTAL PROD	PRICE	$ VALUE
DAIRY I	MILK	130.00	20.00	2600.00	4.41	11465.99
DAIRY I	CULL COWS	0.20	20.00	4.00	150.35	601.40
STEERS	BEEF	10.00	80.00	800.00	24.95	19958.38
CORN II	FEED GRAIN	56.00	30.00	1680.00	2.31	3880.80
CORN III	FEED GRAIN	44.00	20.00	880.00	2.31	2032.80
WHEAT II	WHEAT	40.00	20.00	800.00	1.50	1200.00
SILAGE II	HAY	5.30	30.00	159.00	30.90	4913.09
HAY III	HAY	3.50	30.00	105.00	30.90	3244.50
PASTURE VI	HAY	1.80	80.00	144.00	30.90	4449.59

*In the deterministic version, production per unit is fixed and prices received are subject to specified price trends.

Table 4.—Summary of yield per unit, number of production units, total production, and product prices for probabilistic version*

1. PROBABILISTIC - CASE 1 1970						
ACTIVITY	PRODUCT	PROD/UNIT	NO. UNITS	TOTAL PROD	PRICE	$ VALUE
DAIRY I	MILK	82.76	20.00	1655.20	4.42	7321.54
DAIRY I	CULL COWS	0.17	20.00	3.44	147.82	508.24
STEERS	BEEF	9.78	80.00	782.13	26.00	20334.45
CORN II	FEED GRAIN	69.37	30.00	2081.21	2.36	4909.27
CORN III	FEED GRAIN	26.32	20.00	526.41	2.36	1241.71
WHEAT II	WHEAT	32.61	20.00	652.11	1.58	1030.92
SILAGE II	HAY	4.53	30.00	135.87	31.34	4258.39
HAY III	HAY	4.08	30.00	122.40	31.34	3836.00
PASTURE VI	HAY	1.93	80.00	154.26	31.34	4834.77

*In the probabilistic version, production per unit is subject to random deviations. Product prices are subject to random deviations and specified price trends.

Table 5.—Results of the simulated year's operations for deterministic version of the farm situation.

1. DETERMINISTIC - CASE 1 1970.

RESOURCES AND ORGANIZATION	
ASSETS	
TRACTOR	233.33
PLOW	552.00
MOWER	854.00
DRILL	525.00
PLANTER	222.00
PICKER	750.00
HARVESTER	300.00
SPREADER	125.00
BARN.DAIRY	5500.00
GEN BARN	3040.00
LAND II	16853.98
LAND III	9922.48
LAND VI	2080.80
DAIRY COWS	8000.00
HARROW	38.00
CASH	13560.90
TOTAL ASSETS	62557.47
DEBTS	
REAL ESTATE DEBT	20856.28
CHATTEL DEBT	2000.00
OTHER DEBT	1665.52
TOTAL DEBTS	24521.79
NET WORTH	38035.68
LABOR	
FAMILY HOURS	2560.00
HIRED.HOURS	1850.00
TOTAL LABOR	4410.00
MAN EQUIV.	1.47
LIVESTOCK	
DAIRY I	20.00
STEERS	80.00
CROP	
CORN II	30.00
CORN III	20.00
WHEAT II	20.00
SILAGE II	30.00
HAY III	30.00
PASTURE VI	80.00

FINANCIAL SUMMARY	
OPERATING INCOME	
MILK	11465.99
BEEF	19958.38
FEED GRAIN	830.68
HAY	4264.18
CULL COWS	601.40
WHEAT	1200.00
CASH OPERATING INCOME	38320.62
CAPITAL ASSETS SOLD	3274.99
GROSS FARM INCOME	41595.62
OPERATING EXPENSE	
REPAIR AND MAINTENANCE	476.85
PROPERTY TAXES	501.28
INSURANCE	230.44
INTEREST	1916.96
OTHER LOAN COST	180.00
TRACTOR	1190.00
COMBINE	90.40
LAND II	400.00
LAND VI	200.00
LABOR 1Q	723.00
LABOR 2Q	855.00
LABOR 3Q	669.00
LABOR 4Q	528.00
SUPPLEMENT	832.50
CASH COST	10264.20
CASH OPERATING EXPENSE	19057.63
NET CASH OPERATING INCOME	19263.00
INVENTORY DECREASE	534.38
CAPITAL PURCHASES	13060.00
GROSS FARM EXPENSE	32652.00
NET FARM INCOME	8943.61
INCOME TAX (CASH BASIS)	1032.98
SOCIAL SECURITY TAX	405.90
PAYMENT ON DEBT PRINCIPAL	3263.21
INTEREST ON INVESTMENT	2955.83
LABOR AND MGT. RETURNS	7904.75
RETURNS PER MAN	5377.38
OFF FARM INCOME	2000.00
WITHDRAWALS	4000.00

Table 6.—Results of the simulated year's operations for probabilistic version of the farm situation.

1. PROBABILISTIC - CASE 1 1970.

RESOURCES AND ORGANIZATION	
ASSETS	
TRACTOR	233.33
PLOW.	552.00
MOWER	854.00
DRILL	525.00
PLANTER	222.00
PICKER	750.00
HARVESTER	300.00
SPREADER	125.00
BARN.DAIRY	5500.00
GEN BARN	3040.00
LAND II	16853.98
LAND III	9922.48
LAND VI	2080.80
DAIRY COWS	8000.00
HARROW	38.00
CASH	10589.82
TOTAL ASSETS	59586.39
DEBTS	
REAL ESTATE DEBT	20856.28
CHATTEL DEBT	2000.00
OTHER DEBT	1665.52
TOTAL DEBTS	24521.79
NET WORTH	35064.60
LABOR	
FAMILY HOURS	2560.00
HIRED HOURS	1850.00
TOTAL LABOR	4410.00
MAN EQUIV.	1.47
LIVESTOCK	
DAIRY I	20.00
STEERS	80.00
CROP	
CORN II	30.00
CORN III	20.00
WHEAT II	20.00
SILAGE II	30.00
HAY III	30.00
PASTURE VI	80.00

FINANCIAL SUMMARY	
OPERATING INCOME	
MILK	7321.54
BEEF	20334.45
FEED GRAIN	960.57
HAY	4467.11
CULL COWS	508.24
WHEAT	1030.92
CASH OPERATING INCOME	34622.83
CAPITAL ASSETS SOLD	3274.99
GROSS FARM INCOME	37897.82
OPERATING EXPENSE	
REPAIR AND MAINTENANCE	476.85
PROPERTY TAXES	501.28
INSURANCE	230.44
INTEREST	1916.96
OTHER LOAN COST	180.00
TRACTOR	1190.00
COMBINE	90.40
LAND II	400.00
LAND VI	200.00
LABOR 1Q	723.00
LABOR 2Q	855.00
LABOR 3Q	669.00
LABOR 4Q	528.00
SUPPLEMENT	832.50
CASH COST	10264.20
CASH OPERATING EXPENSE	19057.63
NET CASH OPERATING INCOME	15565.20
INVENTORY DECREASE	534.38
CAPITAL PURCHASES	13060.00
GROSS FARM EXPENSE	32652.00
NET FARM INCOME	5245.82
INCOME TAX (CASH BASIS)	356.78
SOCIAL SECURITY TAX	355.39
PAYMENT ON DEBT PRINCIPAL	3263.
INTEREST ON INVESTMENT	2955 3
LABOR AND MGT. RETURNS	4206.95
RETURNS PER MAN	2861.87
OFF FARM INCOME	2000.00
WITHDRAWALS	4000.00