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LINEAR PROGRAMMING A NEW YORK DAIRY FARM

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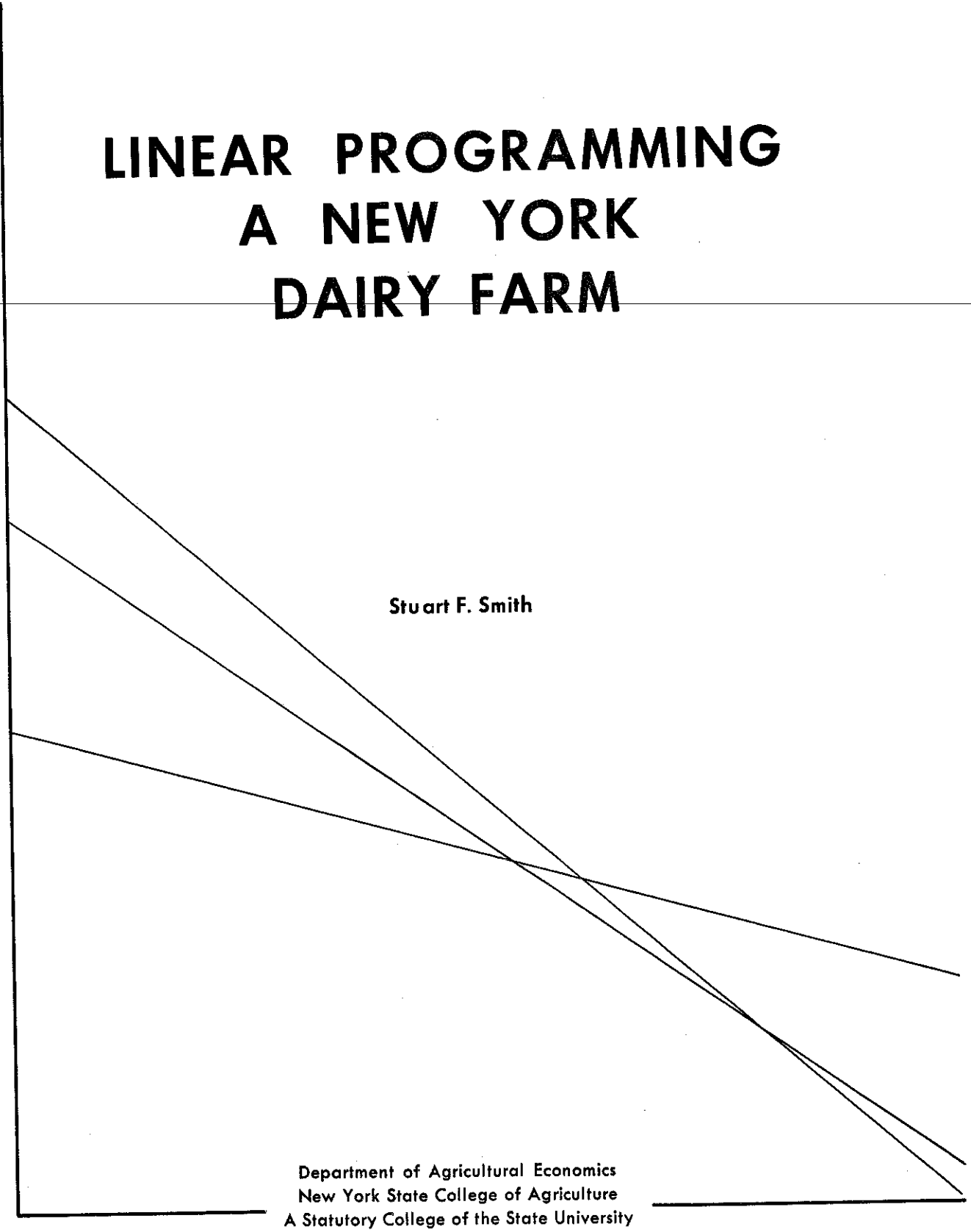

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INTRODUCTION

Objectives

The purposes of this bulletin are:

1. To show how linear programming can be used to help a New York dairyman plan for future changes;

2. To familiarize the reader with linear programming procedures, and;

3. To point out usefulness and limitations of linear programming in farm management work.

Application

Linear programming is a mathematical method which may be used to maximize or minimize a given objective such as "profit," subject to certain limitations or restrictions. It can be used most efficiently when there are many alternative processes or activities under consideration, and several restrictions on resources. Linear programming has been used most extensively in areas such as feed mixing, transportation, and plant location. Budgeting can be applied more efficiently to a single enterprise business having a small number of production processes. Although alternative enterprises are limited on most New York dairy farms, the number of different production processes associated with the dairy enterprise are often numerous and the availability of resources is limited. Thus linear programming appears to have potential as a planning technique for dairy farms.

In 1969 linear programming was used to find the combination of activities and processes that would maximize the return to fixed resources on a real New York dairy farm. Because of the confidential nature of individual farm business data, we will call this the Plan-Now Farm. The alternative plans or solutions presented for the Plan-Now Farm cannot be directly used for decision making by any other farm manager since resource mix and limitations vary with each farm situation. However, the plans may have some value as a guide to dairymen with similar resources. The linear programming procedures used on this farm should be of value to the farm management worker interested in this forward planning technique.

Information Needed

The information needed to develop a farm plan by linear programming is similar to that used in budgeting, with considerable more detail re-

quired. Input-output data for all feasible production, buying and selling processes and activities must be carefully defined. Restrictions affecting the use of processes and activities must be identified and planning objectives must be specified.

In linear programming, a technique such as the production of corn silage on a particular field with a given set of inputs is one process. If one production technique differs from another in type, proportions, or timing of the resources it uses, the two are treated as separate processes. The program also includes every feasible buying and selling opportunity as a separate activity.

In order to develop the process and activity data, the amount and unit cost of each variable must be determined. These variable coefficients correspond to the feed, labor, and capital requirements used in budgeting, and most individual production processes require a different set of coefficients. Coefficients for crops include the yield from one acre, and the inputs of fertilizer, labor, machinery, and other variable items for this acre.

Determining expected price levels is an important part of programming. Prices effect the costs incurred by all production processes and buying activities as well as revenues realized through selling activities. Emphasis is placed on accurate relative prices rather than the exact level of prices used.

The identification of specific restrictions for the linear programming model is quite different than the budgeting approach. Although general restrictions affect the amount and kind of resources considered in a budgeting problem, specific restrictions such as the labor available in a given month are seldom considered.

Given the restrictions, prices, production coefficients, and selected activities, linear programming will specify the plan which will give maximum net income. This is called the optimum solution. However, other objectives or operator goals such as avoiding risk or working with a particular enterprise need not be ignored. The model can be constructed to force certain processes into the solution, restrictions can be imposed to force out certain processes, or, processes can be omitted from the original model.

Programming Procedure

There were six basic steps followed in programming the Plan-Now Dairy Farm. They are as follows:

(1) Obtain the primary data from the farm and other sources.

(2) Process the primary data into activity and constraint form.

(3) Transfer the data to computer cards.

(4) Make a "test" or preliminary run on the computer.

(5) Make the necessary corrections and adjustments to data and make a second run.

(6) Make additional runs following desired changes in processes and constraints.

The Plan-Now Dairy Farm was visited twice to obtain information on present resources, feasible activity and process considerations, operator goals and availability of resources for the future. Some of this information was obtained by corresponding with the farm operator between visits. The Plan-Now Farm Electronic Accounting Summary was used to help determine some of the cost and production coefficients and establishing price ratios. Since only variable production costs are used in the model, additional cost data and estimates had to be obtained from other sources. Agricultural Planning Data for the Northeastern United States, Pennsylvania State University, A.E. and R.S. 51, July 1965, was one of the data sources used. After an examination of the process and activity budgets, the limited contribution of conventional cash account and electronic records to linear programming will become more obvious.

Processing the primary data into activity and constraint form is an important and time consuming process. The inexperienced programmer will spend from one to three hours developing each process activity. This time requirement depends upon the availability of bench mark farms and the similarity of production processes within the program being developed. Bench mark farms could help provide some of the basic information such as labor and machine requirements for a given crop. Construction of the matrix format so that each process is in proper perspective and that all necessary controls and constraints have the correct role, is a fascinating and rigorous process.

Preparing data lists for card punching is a mechanical process which involves listing all the activity and constraint information in the correct order and format. This requires some basic knowledge of the computer program requirements. The Cornell University MPS/360 program was used for this linear programming problem.

Steps 4, 5, and 6 involve making several runs. More than one run may be needed to obtain the first optimum solution. Once the first optimum solution is obtained, a whole series of changes may be desirable to test the results of using different production processes and restrictions. This worker made three runs to get the first optimum solution. The changes and program adjustments made will be explained along with the presentation of results. The changes and program adjustments will be explained along with the presentation of results.

The following information is presented in the next section of this report:

(1) A summary of the Plan-Now Farm resources.

(2) An outline of the activities and processes considered in the basic program.

(3) A sample activity budget with explanation.

(4) A simplified version of the programming matrix.

The program solutions are presented in the third section. Six activity budgets are presented in the appendix.

INPUT DATA USED

Plan-Now Farm Resources

Land

There are 165 acres of tillable land owned. The majority of this cropland is well-drained and is adaptable to intensive cropping. There are 75 acres of Unadilla soil, 40 acres of Tioga soil, and 50 acres of a combination of moderately well-drained, stoney soils. All the Tioga soil is on the first bottomland adjacent to the farmstead. The Unadilla is in two separate parts, one is located five miles from the farmstead.

Building Capabilities

The present dairy housing facility is a combination of a 40 stanchion barn and a 40 cow free stall shed. All cows are milked in the stanchion barn, there are 70 head of youngstock on the Plan-Now Farm. Present youngstock facilities are inconvenient.

The dairy herd is self-fed from a 1500 ton capacity trench silo that can be used to store corn silage. A 14 x 55 cement stave silo is equipped with a silo unloader and will store 200 tons of hay crop silage or high moisture ear corn.

Equipment

Adequate field equipment is available to handle all crops to be considered except for harvesting high moisture ear corn.

Labor

The operator, one full-time hired man, and approximately five months of family labor are available at a fixed quantity and rate. Part-time labor is available for field work at $1.75 per hour.

Resource Limitations

In developing the first model it is assumed no additional resources may be purchased. Therefore, the following restrictions are placed on the use of resources:

(1) Any combination of production processes on Unadilla soil must be less than or equal to 75 acres.

(2) Production processes on Tioga soil must be less than or equal to 40 acres.

(3) All processes on other soil cannot exceed 50 acres.

(4) Cow numbers must be equal to or less than 80 head.

(5) Replacement numbers must be adequate to turnover at least 25% of the cow herd each year.

(6) Corn silage production may not exceed 1500 tons per year.

(7) Hay crop silage plus high moisture ear corn production must be less than or equal to 200 tons.

(8) There are 600 hours of fixed labor available per month with hired labor allowed from April through November. Therefore, labor may not exceed 2500 hours from December 1 through March 31.

Production Processes and Activities

Following are the processes and activities considered in the first or basic plan, the objective of the basic plan is to find an optimum solution to which alternative plans can be compared. A general description of each process and specific controls or limitations affecting its use are included.

P. 1, Grow 3-Year Alfalfa on Unadilla Soil

An annual production process for growing alfalfa on Unadilla soil. All cropland used for this process must be left in production for three years. Additional activities are required to harvest the alfalfa.

P. 2, 3-Year Hay on Unadilla Soil

This is the 3-year alfalfa crop harvested as hay. The activity budget shows annual yields and variable costs for this activity.

P. 3, 3-Year Silage on Unadilla Soil

The 3-year alfalfa crop is harvested as hay-crop silage. Any combination of processes 2 and 3 must equal the acres in process 1.

P. 4, Grow Alfalfa for the 4th and 5th Years on Unadilla

The alfalfa grown in P.1 is left down for two additional years. For every three acres of Unadilla in P.1, two acres of P.4 are allowed.

P. 5, 4th and 5th Year Alfalfa Hay on Unadilla Soil

If activity P.4 is used the crop may be harvested as hay.

P. 6, 4th and 5th Year Alfalfa Silage on Unadilla Soil

The 4th and 5th year alfalfa stands may also be harvested as hay-crop silage. The acres used in P.5 and P.6 may not exceed the acres in P.4.

P. 7, Seeding Year on Unadilla Soil

If alfalfa is grown on this soil it must be seeded. The seeding year would be followed by either three or five years of alfalfa. Alfalfa is seeded without a nurse crop and is harvested the seeding year.

P. 8 and P. 9, Corn Silage or Corn Grain on Unadilla

Corn silage and/or corn grain may be produced on Unadilla soil. There is no limit on the length of the corn rotation, but at least two years of corn are required in each rotation. Corn grain is harvested as high moisture ear corn and stored in an upright silo. Corn silage is harvested and stored in the trench silo.

P. 10 and P. 11, Corn Silage or Corn Grain on Tioga

Corn silage and/or corn grain are the only crops that are considered on the 40 acres of Tioga soil. This land is most adaptable to continuous corn, it is highly productive and most accessible for manure disposal.

P. 12, 5-Year Hay on Other Soil

A 5-year hay crop may be grown and harvested from other soils. Harvesting the hay crop as silage has not been allowed on this soil.

P. 13, Pasture, Other Soil

Some of the meadows included in P.12 may be pastured but this alternative is limited to 15 acres per year because of access.

P. 14, Seeding year on Other Soil

The other soil must be seeded to a legume preceding the five years of hay.

P. 15 and P. 16, Corn Silage or Corn Grain on Other Soil

Corn silage or corn grain must be produced for two years preceding the seeding year.

P. 17, Cows

A maximum of 80 cows may be kept without a major change in facilities. They will produce 12,500 pounds of milk for sale and will require 5300 pounds[1/] of TDN from forage, 3500 pounds of TDN from grain, and 1160 pounds of digestible protein.

P. 18 and P. 19, Replacements

Opportunity is provided to either buy (P.18) or raise (P.19) replacements. Cows will be replaced every four years.

P. 20 and P. 21, Buy Hay

Hay may be purchased as standing (P.20) or as baled hay (P.21). Standing hay purchased may not exceed 50 acres.

P. 22, Sell Hay

Hay produced on the farm may be sold.

P. 23 - P. 26, Buy Concentrate

Four different levels of protein concentrate or supplement may be purchased to balance the dairy herd feeding requirement. Each cow requires a minimum of 3500 pounds of TDN from grain. The protein needed from purchased concentrate will vary depending upon the quantity and quality of forage and home-grown grain fed. The linear programming model is constructed to select combinations of purchased concentrates that will balance total protein requirements as well as meeting TDN needs. P.23 is a 15% total protein concentrate and P.24 is 20%. P.25 is the amount of 27% protein supplement to mix with high moisture ear corn and P.26 is 36% supplement. P.25 and P.26 would be used only if high moisture ear corn was in production at the optimum.

The grain required by raised replacements is provided through activity P.23.

P. 27, Sell Corn

Corn grain may be sold.

1/ After the first optimum solution was obtained, forage TDN required per cow was increased to 6000 pounds to more nearly reflect production requirements rather than only feeding requirements.

P. 28, Sell Milk

Milk produced by activity P.17 is transferred and sold for $5.30 per cwt. This is the gross price less hauling and marketing costs paid by the farmer. Selling milk is the major income producing activity. The price could easily be changed to another level without affecting the coefficients established for P.17.

P. 29 - P. 36, Hire Labor

Day labor may be hired during an eight-month period of April through November for $1.75 per hour.

Activity Variations and Additions

The preceding production processes and activities were selected for the basic plan because all seemed feasible and applicable to this farm situation. All the production processes had been used on the Plan-Now Farm except high moisture ear corn. The farmer had no interest in considering any other crops or livestock enterprises. However, additional processes and activities such as the production of wheat, oats, dried shell corn, and the sale of youngstock, feeder calves and Christmas trees could be added without changing the production coefficients already determined.

It may be more efficient to combine certain production practices and consider them as a complete rotation. This is true when there are a limited number of rotation alternatives on a given soil, involving several crops. For example, a rotation including five years of hay, two years of corn silage and one year of seeding could be designated as one process providing all acres were produced and harvested in a similar manner.

The combination of like processes may create programming problems. For example, one set of inputs is used for corn silage production on Unadilla soil. One should consider using different fertilizer requirements for the intensive and extensive corn rotations.

The cost of capital to the farm operator is an important consideration. The Plan-Now Farm basic plan does not include an activity to borrow capital for it was assumed adequate operating capital was available. When expansion activities were brought into the plan, interest was included as part of the variable cost.

The cost of money should be considered by some method. Including an activity for short-term capital is recommended for the use of all capital that has some opportunity cost.

Expansion activities were included as alternatives after the optimum solution for basic plan was determined. The expansion activities and corresponding changes made in resource restraints and input coefficients are defined in succeeding sections.

Activity Budgets

Each production process or activity requires a certain quantity and quality of inputs for each unit of output. Budgets are developed for each process in order to determine input requirements and output contributions.

Sample Budget

The budget for P.1, Grow 3-Year Alfalfa on Unadilla Soil, is presented in Table 1. It was developed in the following manner.

Alfalfa grown under an intensive three-crop, three-year system would yield approximately 3.5 tons of hay equivalent under Plan-Now Farm conditions and management. This yield is equivalent to 3640 pounds of TDN and 840 pounds of digestible protein per acre. TDN was calculated at 52% and digestible protein at 12%. Yields are transferred to the corresponding harvesting activities for this crop. The cost of establishing the alfalfa are included in P.7, seeding year on Unadilla soil. The annual variable costs of maintaining the alfalfa stand included in this activity are:

(1) 300 pounds of 0-15-30 fertilizer per acre at $61.50 per ton.

(2) Fertilizer custom applied for $1.50 per acre.

(3) Alfalfa weevil control will average $2.88 per acre including the cost of materials, $2.75; and the estimated variable cost of operating the tractor and sprayer, $0.13.

The only farm labor requirement is 0.15 hours per acre for weevil control during June.

Budget Summary

A summary of all the feed producing process or activity budgets is presented in Table 2. Processes that consume feed or use some limited resource are in Table 3. The only activities not included in Tables 2 and 3 are the labor purchasing activities which require no further explanation.

Additional detailed activity budgets are included in the appendix.

TABLE 1

BUDGET FOR ACTIVITY P1, GROW 3-YEAR ALFALFA,
Unadilla Soil

Average Annual Yields, 3 crop system:

Crop	TDN, lbs/acre[1/]	Hay equivalent, tons/acre
1	1729	1.73
2	1118	1.07
3	1110	1.04
Total adjusted for loss (10%)	3640 (Digestible protein = 840 pounds)	3.50

Variable Growing Costs per acre per year:

	Cost per acre
Fertilizer (300 lbs. 0-15-30)	$ 9.23
Custom application, fertlizer	1.50
Weevil Control (materials)	2.75
(tractor & sprayer costs)	0.13
TOTAL annual, variable cost	$13.61

Labor Requirement:

	Hours/acre	Month
Weevil Control	0.15	June

1/ TDN was calculated at 52%, and digestible protein at 12%.

TABLE 2

SUMMARY OF FEED PRODUCING

Activity Budgets

Production Process	Unit	Hr. of Labor /unit/yr 1/	Tons Per Unit	TDN Per Unit	Dig.Pro. Per Unit	Variable cost/unit 2/
				lbs.	lbs.	dollars
P1 G3YRALFU	1 acre	.15	----	----	----	13.61
P2 3YRHAYU	1 acre	6.43	3.5	3640	840	8.76
P3 3YRSILU	1 acre	3.48	8.0	3640	900	7.37
P4 G45RALU	1 acre	.15	----	----	----	10.73
P5 45YRHAYU	1 acre	5.94	3.0	3218	648	7.93
P6 45YRSILU	1 acre	3.13	6.5	3120	770	6.56
P7 SEEDU	1 acre	5.80	1.5	1750	324	58.37
P8 CRNSILU	1 acre	5.17	16.	6400	512	45.48
P9 CRNGRU	1 acre	3.19	4.0	4640 3/	344 3/	43.94
P10 CRNSILT	1 acre	7.26	25.	9999	800	42.06
P11 CRNGRT	1 acre	4.56	6.25	7250 3/	538 3/	39.42
P12 5YRHAYO	1 acre	6.39	3.0	3432	792	22.64
P13 PASTO	1 acre	1.55	----	2808	648	15.11
P14 SEEDO	1 acre	5.80	1.5	1750	324	58.37
P15 CRNSILO	1 acre	5.17	16.	6400	512	45.48
P16 CRNGRO	1 acre	3.19	4.0	4640 3/	344 3/	43.94
P20 BUYSTHAY	1 ton	3.34	1.75	1750	280	17.30
P21 BUYBHAY	1 ton	.25	1.0	1000	240	30.00
P23 15GRN	1 cwt.	----	----	72	12	3.75
P24 20GRN	1 cwt.	----	----	62.1	15	4.05
P25 27GRNHMC	1 cwt.	.12	----	61.4	10.6	1.62 4/
P26 36GRNHMC	1 cwt.	.12	----		13.3	1.70 4/

1/ Refer to programming matrix for monthly labor requirements.

2/ Refer to appendix for breakdown of variable costs on selected activities.

3/ TDN and digestible protein from high moisture ear corn is transferred to and included in processes 25 and 26.

4/ Cost of producing high moisture ear corn is charged to P.9, P.11, and P.16.

TABLE 3

SUMMARY OF FEED CONSUMPTION AND
Selling Activity Budgets

Process	Unit	Hrs. of Labor /unit/year	TDN per unit	Dig.Pro. per unit	Return Over Variable cost/unit
			lbs.	lbs.	Dollars
P17 COWS	1 head	69.6	8850	1160	$ 11.00
P18 RASREPL[1/]	1 head	43.6	5120	1064	-73.00
P19 BUYREPL	1 head	----	----	----	450.00
P22 SELLHAY	1 ton	.25	1040	258	28.00
P27 SELLCRN	1 ton	.50	1160	86	22.50
P28 SELLMILK	1 cwt.	----	----	----	5.30

1/ Requirements are for raising one animal to freshening age or 27 months.

Programming Matrix

The matrix format is developed to determine and show the specific relationship of all activities, constraints, controls and transfers. The basic Plan-Now Farm matrix includes 36 columns or activities and 36 rows for constraints, controls and transfers.

A simplified version of the programming matrix developed for the Plan-Now Farm is shown in Table 4. There are 16 processes or activities in columns followed by one constraint column. The first row contains the net return or variable cost of each activity. Economists call this the objective function. P.17 and P.28 are the only activities presented in Table 4 that produce a net return over variable costs. All other activities result in a net cost to the program. Rows two through 16 contain constraints, controls or transfers. Their relationship and effect on the various activities is explained below.

CLANDU is the constraint on the amount of Unadilla cropland available. Any combination of production processes P.1, P.4, P.7, P.8 and P.9 may not exceed 75 acres.

4,5ALF ties the production of fourth and fifth year alfalfa to the three year rotation. Alfalfa must be grown for three years before the fourth and fifth years of production can be obtained.

RESEEDA provides for one acre of seeding activity for every three acres of P.1.

HAYCNTA is a control that ties the growing and harvesting of alfalfa together.

PRESCOW is the constraint which prohibits cow numbers from exceeding 80.

Lines 07, 08, and 09 are the hours of labor required by the various processes for June, September and the winter period of December through March. The constraint column shows that there are 600 hours of fixed labor available in June and September, and 2400 hours available during the four-month winter season. When the hours of fixed labor are exhausted, hired labor can be purchased in April through November from activities P.29 through P.36 (not shown).

REPLACMENT, line 10, controls the number of replacements that must be raised or purchased. One-fourth of the cows will be replaced each year.

MILKSOLD transfers the 12,500 pounds of milk produced by each cow to the milk selling activity.

REPLGRN transfers the grain required by youngstock to the 15% grain buying activity. Each replacement grown to 27 months or age will require 1600 pounds of 15% protein grain.

CRNPROD transfers the 7000 pounds of 33% moisture ear corn produced per acre to activity 25 which uses 63.2 pounds for each 36.8 pounds of 27% grain purchased.

Lines 14 and 15 transfer TDN and digestible protein produced and purchased to the feed consuming activities. The complete matrix also has a transfer row for TDN in grain.

STHAY limits the amount of standing hay purchased to 50 acres or less.

TABLE 4

PROGRAMMING MATRIX (SIMPLIFIED VERSION)

	Constraints Controls Transfers	Production Processes and Activities								
		P1 G3YR ALFU	P2 3YR HAYU	P3 3YR SILU	P4 G45Y RALU	P5 45YR HAYU	P6 45YR SILU	P7 SEED U	P8 CRN SILU	P9 CRN GRU
01	NETRETRN/ VARBCOST	-13.61	-8.76	-7.37	-10.73	-7.93	-6.56	-58.37	-45.48	-43.94
02	CLANDU	1			1			1	1	1
03	4,5ALF	-2			3					
04	RESEEDA	1						-3		
05	HAYCNTA	-1	1	1						
06	PRESCOW									
07	JUNLAB	.15	2.67	1.50	.15	2.20	1.29	.15		
08	SEPLAB		.94						2.65	
09	WINTLAB									
10	REPLACMT									
11	MILKSOLD									
12	REPLGRN									
13	CRNPROD									7000
14	TDNFOR		-3640	-3640		-3218	-3120	-1750	-6400	
15	PROT		- 840	- 900		- 648	- 770	- 324	- 512	
16	STHAY									

TABLE 4 cont'd

PROGRAMMING MATRIX (SIMPLIFIED VERSION)

Production Processes and Activities

	P17 COWS	P18 RAS REPL	P19 BUY REPL	P20 BUY STHAY	P23 15 GRN	P25 GRN HMC	P28 SELL MILK	P31 LAB JUN	P34 LAB SEP	CONSTRAINTS
01	11.00	-73.00	-450.0	-17.30	-3.75	-1.62	5.30	-1.75	-1.75	
02										≤ 75
03										
04										
05										
06	1									≤ 80
07	5.20	4.00				.01		-1.0		≤ 600
08	6.10	2.90				.01			-1.0	≤ 600
09	24.40	16.00				.04				≤ 2400
10	1	-4	-4							
11	-125						1			
12		16			-1.0					
13						-63.2				
14	5300	4000		-1750						
15	1160	1064		- 280	-12	-10.6				
16				1.0						≤ 50

PROGRAMMING RESULTS

First Optimum Solution Plan-Now Farm

The optimum solution for the basic linear programming model which does not allow expansion is summarized in Table 5. The activities in solution and the level at which they should be used are identified. Any change in this combination of activities and processes would increase variable costs and reduce profits.

The optimum solution for the basic program is quite similar to the program now being followed on the Plan-Now Farm except for the intensity of the cropping program. The farmer is growing more corn silage, less hay, and has a smaller hay surplus available for sale.

In most cases units of measure have been rounded off and expressed as whole numbers. Therefore, 78 cows divided by 20 replacements does not exactly equal the required 4/1 ratio.

Return to Fixed Resources (Basic Plan) $40,303

The profitability of the optimum solution produced with the basic model was $40,303. This is the return to fixed resources or the return over variable costs. The variable costs associated with each selected activity have been deducted from the total revenue accumulated by the selling activities used. To provide an estimate of net farm income, it is necessary to deduct fixed costs from the return over variable costs. Following is an estimate of fixed costs:

Fixed Labor Force	$ 6,000
Machine & equipment depreciation (45,000 @ 14%)	6,300
Real estate depreciation and upkeep	500
Taxes and insurance	1,500
Telephone and fixed utilities	800
Miscellaneous overhead costs	500
TOTAL FIXED COSTS	$15,600
Return over variable costs less fixed costs:	$24,700
less interest on capital invested (6% of $160,000)	- 9,600
Approximate return to operator's labor and management	$15,100

TABLE 5

LEVEL AND IDENTIFICATION OF ACTIVITIES

First Optimum Solution

Level	Activity	
27 acres	P.1	Grow 3-year alfalfa on Unadilla soil.
27 acres	P.2	Harvest P.1 as hay.
18 acres	P.4	Grow 4th and 5th year alfalfa on Unadilla soil.
12 acres	P.5	Harvest 4th and 5th year alfalfa as hay.
6 acres	P.6	Harvest 4th and 5th year alfalfa as silage.
9 acres	P.7	Seeding year, Unadilla.
21 acres	P.8	Corn silage, Unadilla.
14 acres	P.10	Corn silage, Tioga.
26 acres	P.11	Corn grain, Tioga.
31 acres	P.12	5-Year hay, other soil.
6 acres	P.14	Seeding year, other soil.
13 acres	P.15	Corn silage, other soil.
78 head	P.17	Cows
20 head	P.18	Replacements raised.
50 acres	P.20	Standing hay bought.
230.5 tons	P.22	Hay sold.
15.6 tons	P.23	15% grain purchased.
83.0 tons	P.26	36% supplement.
9750.00 cwt.	P.28	Milk sold.
16 hours	P.29	Hired Labor, April
44 hours	P.30	Hired Labor, May
106 hours	P.31	Hired Labor, June
147 hours	P.32	Hired Labor, July
216 hours	P.34	Hired Labor, September
188 hours	P.35	Hired Labor, October
39 hours	P.36	Hired Labor, November

Marginal Values

The marginal value of a limiting resource is the added return that could be realized if one additional unit of this resource were made available to the plan. This assumes that the costs incurred in utilizing this unit of resource and the value of output from this unit, would remain the same.

TABLE 6

MARGINAL VALUES OF LIMITING RESOURCES

Resource	Marginal Value
Cropland, Unadilla	$34.28 per acre
Cropland, Tioga	83.98 per acre
Cropland, other	34.01 per acre
Winter Labor	10.19 per hour
Standing Hay	9.60 per acre

One additional acre of Unadilla cropland would add $34.28 to income or the Plan-Now Farm could afford to pay as much as $34.28 annually for one additional acre of this land. The marginal values of the other limiting resources listed above should be interpreted the same way. One additional acre of standing hay would add $9.60 to net income.

The Plan-Now Farm operator cannot expect the marginal values to remain constant as unlimited amounts of resources are added. The marginal value of Unadilla cropland may be $34.28 per acre for the addition of 20 acres with the 21st acre at $15.

Penalty Costs

The penalty cost of introducing an activity not in the solution indicates that the value of the program would be reduced if one of these activities were used in place of an activity now in the solution. It can also be interpreted as the amount the cost of these activities would have to be reduced before it would be profitable to introduce one unit into the solution. The figures in parentheses show the range over which the penality cost would remain constant.

TABLE 7

PENALTY COST OF INTRODUCING ACTIVITIES NOT IN SOLUTION

First Optimum Solution

	Activity	Penalty Cost
P.3	Harvest 3-year hay silage, Unadilla (5 acres)	$ 5.44 per acre
P.9	Corn grain, Unadilla (21 acres)	0.25 per acre
P.13	Pasture, other (3 acres)	0.33 per acre
P.16	Corn grain, other soil (12.5 acres)	0.24 per acre
P.18	Buy replacements (20 head)	23.00 per head
P.21	Buy baled hay (8.8 tons)	6.45 per ton
P.24	Buy 20% grain	0.54 per cwt.
P.25	Buy 27% grain	0.16 per cwt.
P.27	Sell Corn	3.62 per ton

If the Plan-Now Farm operator decided to harvest five acres of 3-year alfalfa grown on Unadilla as silage rather than hay, he would reduce profits $5.44 per acre or $27.20. If he decided to sell corn to a neighbor, the Plan-Now manager must charge $3.62 more per ton to avoid a loss. However, corn grain could be substituted for corn silage on Unadilla at a very small loss in revenue.

Changes Affect Solution

The preceding solution is a product of the yields, feed and labor requirements and other input-output relationships used. Results depend on the restrictions imposed by the operator and the programmer, as well as the price levels used. It is the optimum plan given these values and assumptions are correct. A change in any one of these factors could change the optimum solution.

For example:

1) A small increase in yield of corn silage on Unadilla soil or a small decrease in the variable cost per acre could double the acreage of this activity used in the solution.

2) A decrease in the monthly labor requirement of keeping cows on this farm would have increased the number of cows in the solution.

3) If the difference between buying and raising replacements were reduced by $23 per head, the optimum solution would include buying replacements.

4) If the activity to buy standing hay were not limited to 50 acres, a considerably higher acreage may have been included. If this activity were eliminated, the optimum solution would change substantially.

Adjustments Made in Input Data

After the basic optimum solution was evaluated, it was decided that there were two previous assumptions affecting the results that should be revaluated and adjusted.

We had previously assumed that the standard TDN requirements for maintenance and milk production could be used to establish the forage and grain requirements used in this model. We found the forage requirements based on the feeding standard come out significantly lower than the amount farmers report as used or the amount farm management workers recommend. Therefore, the forage TDN requirement was increased from 5300 to 6000 pounds per cow to represent the amount that should be stored to allow for uncertainties of quality, level of production, and storage and feeding losses.

The preceding plan also assumes that the farm operator can hire labor in any month from April through November, and that the number of hours hired in any one month would be independent of the hours hired in any other month. It was decided that this assumption was unrealistic under present farm labor supply conditions. A constraint was added to require labor purchased in the high demand month to also be purchased in all summmer months (May through October).

The plan obtained following these changes is presented as SECOND OPTIMUM SOLUTION.

Second Optimum Solution, Plan-Now Farm

This is the basic plan with the forage TDN requirement increased to 6000 pounds per cow and a constraint added to summer labor. The labor constraint forced extra seasonal labor to be hired at a level established during the high demand month.

The second optimum solution shows a return to fixed resources of $38,739. This is $1,564 less than the return from the first optimum solution. The two changes made in the program have increased the variable cost of production.

TABLE 8

LEVEL AND IDENTIFICATION OF ACTIVITIES

Second Optimum Solution

Level		Activity
25 acres	P.1	Grow 3-year alfalfa on Unadilla.
25 acres	P.2	Harvest P.1 as hay.
16 acres	P.4	Grow 4th and 5th year alfalfa on Unadilla.
10 acres	P.5	Harvest 4th and 5th year alfalfa as hay.
6 acres	P.6	Harvest 4th and 5th year alfalfa as silage.
8 acres	P.7	Seeding year, Unadilla.
26 acres	P.9	Corn grain, Unadilla.
39 acres	P.10	Corn silage, Tioga.
1 acre	P.11	Corn grain, Tioga.
31 acres	P.12	5-Year hay, other soil.
6 acres	P.14	Seeding year, other soil.
13 acres	P.16	Corn grain, other soil.
78 head	P.17	Cows
20 head	P.18	Replacements raised.
50 acres	P.20	Standing Hay purchased.
192 tons	P.22	Hay sold.
15.6 tons	P.23	15% grain purchased.
75.0 tons	P.25	27% supplement purchased.
1.2 tons	P.26	36% supplement purchased.
9750.00 cwt.	P.28	Milk sold.

Return to Fixed Resources: $38,739

A comparison of Table 5 and Table 8 indicates some change in the mix of processes and activities. The second solution includes more corn acreage, less hay acreage and less hay sold. Increasing the forage TDN requirement has resulted in a more intensive cropping program and a reduction of surplus forage.

The Labor Problem

The result of adding the labor constraint is summarized in Table 9. The high labor demand month is September when 796 hours are required. There are only 600 hours of regular labor available in any month so 196 hours of seasonal labor must be hired in September to meet the requirement. The labor constraint forces 196 hours of seasonal labor to be hired in the other five summer months creating unused or slack labor in these months. The largest amount of slack labor occurs in August when only 591 hours are needed to carry on the activities in the solution. Slack labor could be used to carry out tasks and duties not connected with any of the activities in solution. Vacation leave for regular employees and the operator should come during slack labor months.

TABLE 9

COMPARISON OF LABOR AVAILABLE AND REQUIRED

Second Optimum Solution

Month	Labor Hired Hours	Labor Required Hours	Slack Labor Hours
		(Fixed labor available, 600 hours per month)	
April	15	615	0
May	196	650	146
June	196	672	124
July	196	742	54
August	196	591	205
September	196	796	0
October	196	767	29
November	40	640	0

Marginal Values and Penalty Costs

The marginal values of limiting resources and penalty costs of unused activities resulting from the second optimum solution are presented in Tables 10 and 11. The program adjustments have resulted in a higher marginal value on land and a somewhat lower value on winter labor. Penalty costs of producing activities that were also exlcuded in the first optimum solution such as pasture, buying replacements and buying baled hay, have also increased. The penalty cost of selling corn has been reduced more than two dollars per ton.

Two adjustments in program requirements have resulted in many changes in the optimum solution. The changes in marginal values and penalty costs

can be associated with the added labor constraint. If additional land were available some of the slack labor could be employed by certain activities to produce higher returns than before. Introducing activities that require additional labor in the peak demand month will cost more because the extra labor must be hired for the entire six month summer period.

The Plan-Now Farm operator and his linear programming consultants believe the second optimum solution comes from a more realistic plan than the first. The second plan will be used as a base to develop expansion alternatives.

TABLE 10

MARGINAL VALUES OF LIMITING RESOURCES

Second Optimum Solution

Resource	Marginal Value
Cropland, Unadilla	$ 37.87 per acre
Cropland, Tioga	89.26 per acre
Cropland, other	36.70 per acre
Hay silage & HMEC capacity	1.71 per ton
Winter Labor	8.86 per hour
Standing Hay	12.15 per acre

TABLE 11

PENALTY COSTS OF INTRODUCING ACTIVITIES NOT IN SOLUTION

Second Optimum Solution

Activity	Penalty Cost
Corn silage, Unadilla (25 acres)	$ 1.58 per acre
Pasture (3.5 acres)	4.09 per acre
Corn silage, other soil (12.5 acres)	1.58 per acre
Buy replacements (20 head)	41.50 per head
Buy baled hay (9 tons)	6.50 per ton
Buy 20% grain	0.66 per cwt.
Sell corn (34 tons)	1.37 per ton

Two-Man Expanded Business, Plan-Now Farm

Following the second plan expansion activities were introduced to allow the dairy farm enterprise to grow within the restraints of a two-man business. In other words, the restriction holding cow numbers at 80 was eliminated, but the restriction on 2400 hours of winter labor was retained. In order to house more than 80 cows expansion activities were introduced.

Expansion Activities

P.37: Purchase or build a free-stall barn at $300 per cow which is equivalent to an annual ownership cost of $42.60 per cow.

P.38: Purchase or build a milking parlor for $19,500 or annual ownership cost of $2,769. One complete parlor is required for any substantial increase in herd size.

P.39: Purchase additional bulk tank capacity for all cows exceeding 100 at an annual ownership cost of $7.44 per cow.

P.40: & P.41: Purchase additional corn silage capacity for that quantity exceeding 1200 tons at an annual cost of $1.55 per ton and new storage capacity for hay crop silage and HMEC at an annual cost of $2.80 per ton.

P.42: Buy additional cows at $450 per head for an annual cost of $25.95 per head.

Included in the annual ownership cost for each expansion activity is the annual depreciation, repair, taxes, insurance and 6% interest on the average investment.

Changes in the type of dairy housing and milking facilities allowed for corresponding changes in dairy chore labor requirements per cow. Annual chore time per cow was reduced from 69.6 hours to 48 hours for the free stall system. Per unit production and feeding coefficients remained unchanged.

Optimum Solution

The optimum combination of processes and activities for the two-man expanded business plan are presented in Table 12. The return to fixed resources is $40,105. The labor summary, marginal values and penalty costs associated with the two-man business optimum are shown in Tables 13, 14 and 15.

TABLE 12

LEVEL AND IDENTIFICATION OF ACTIVITIES

Two-Man Expanded Business Optimum

Level	Activity	
7 acres	P.1 & P.2	Grow 3-year alfalfa on Unadilla, harvest as hay.
5 acres	P.4 & P.5	Grow 4th and 5th year alfalfa on Unadilla and harvest as hay.
2 acres	P.7	Seeding year, Unadilla.
20 acres	P.8	Corn silage, Unadilla.
41 acres	P.9	Corn grain, Unadilla.
40 acres	P.10	Corn silage, Tioga.
31 acres	P.12	Hay, 5-year, other soil.
6 acres	P.14	Seeding year, other soil.
13 acres	P.16	Corn grain, other soil.
104 head	P.17	Cows
26 head	P.18	Replacements raised.
50 acres	P.20	Standing hay purchased.
47.6 tons	P.22	Hay sold.
20 tons	P.23	15% grain purchased
115.1 tons	P.25	27% concentrate
13000 cwt.	P.28	Milk sold.
104 stall	P.37	Free-stall barn purchased.
1	P.38	Parlor purchased.
4 cows	P.39	Additional bulk tank capacity.
116 tons	P.40	Corn silage capacity purchased.
214 tons	P.41	HMEC storage capacity purchased.
24 head	P.42	Cows purchased.

Return to Fixed Resources: $40,105

TABLE 13

TWO-MAN EXPANDED BUSINESS OPTIMUM

Labor Summary

Month	Labor Hired Hours	Labor Required Hours	Slack Labor Hours
		(Fixed Labor Available, 600 hours per month)	
April	9	609	0
May	214	726	88
June	214	624	190
July	214	604	210
August	214	554	260
September	214	814	0
October	214	808	6
November	54	654	0
Dec. - March	0	2400	0

TABLE 14

MARGINAL VALUES OF LIMITING RESOURCES

Two-Man Expanded Business Optimum

Resource	Marginal Value
Cropland, Unadilla	$ 39.35 per acre
Cropland, Tioga	94.05 per acre
Cropland, other	38.41 per acre
Winter Labor	8.48 per hour
Standing Hay	16.33 per acre

TABLE 15

PENALTY COST OF INTRODUCING ACTIVITIES NOT IN SOLUTION

Two-Man Expanded Business Optimum

Activity		Penalty Cost
P.3	Hay silage, on Unadilla	$ 1.50 per acre
P.11	Corn grain, Tioga (26 acres)	2.35 per acre
P.13	Pasture, other soil (15 acres)	3.81 per acre
P.15	Corn silage, other soil (13 acres)	0.00 per acre
P.19	Buy replacements	44.05 per head
P.21	Buy baled hay	6.08 per ton
P.24	Buy 20% grain	0.61 per cwt.
P.26	Buy 36% supplement	0.19 per cwt.
P.27	Sell Corn	5.00 per ton

The two-man expanded business optimum solution includes the purchase of a 104 free-stall barn, one milking parlor, silo capacity for 330 tons of material and additional bulk tank capacity for the milk from four cows. In practice other alternatives would be available to meet the milk storage requirement.

The introduction of expansion activities has resulted in several major changes in the optimum solution. Cow numbers have increased to 104 head, corn has increased to 114 acres and hay has decreased to 43 acres excluding standing hay purchased. The cropping program has become more intensive although excess hay is still being produced and sold.

The two-man expanded business would provide an increased return to fixed resources of $1,366, if managed at the optimum. All the costs associated with purchasing and owning the new facilities have been included in the expansion activity budgets since they would be avoided if there were no expansion. The $1,366 additional return can be interpreted as increased profits.

September continues as the peak labor demand month. Two-hundred and fourteen hours of labor are hired in each summer month to guarantee its availability in September.

The marginal values show that the use of additional land would be profitable at typical rental rates and additional winter labor is worth

$8.48 per hour. The penalty costs still represent the cost of using activities not in the solution. Corn silage could replace corn grain on the "other" soil without changing the costs and returns at the optimum. This plan has more than one optimum combination of processes.

The most significant change is the increase in cows from 78 to 104 head. Yet this increase of 26 head is only a 33% increase in herd size, and is not as large as one might want to consider. The size of herd is not being restricted by lack of facilities. The winter labor constraint is preventing cow numbers from increasing. If additional winter labor were made available we would expect another increase in cow numbers.

Three-Man Business Plan-Now Farm

The constraint on winter labor was relaxed to allow an optimum solution for a three-man business. The fixed labor force was increased by one full-time employee which provides a total fixed labor force of three men plus 0.4 man equivalent as family help. The fixed labor force now supplies 850 hours per month.

No other changes were made to constraints or processes. Since costs incurred by hiring the second full-time employee have not been included in the plan, the return to fixed resources must be reduced by these costs when comparisons are made. The optimum combination of processes and activities for the three-man business are presented in Table 16. Other results from the three-man optimum solutions are presented in Tables 17 through 19.

TABLE 16

LEVEL AND IDENTIFICATION OF ACTIVITIES

Three-Man Business Optimum

Level	Activity
56 acres	P.8 Corn silage, Unadilla.
19 acres	P.9 Corn grain, Unadilla.
40 acres	P.10 Corn silage, Tioga.
31 acres	P.12 5-Year hay, other soil.
6 acres	P.14 Seeding, other soil.
13 acres	P.15 Corn silage, other soil.
159 head	P.17 Cows
40 head	P.18 Replacements raised.
50 acres	P.20 Standing hay purchased.
72 tons	P.21 Baled hay purchased.
333.6 tons	P.23 15% concentrate purchased.
38.6 tons	P.25 27% concentrate purchased.
198750 cwt.	P.28 Milk sold
159 cows	P.37 Free-stall barn purchased.
1	P.38 Milking parlor purchased.
59 cows	P.39 Additional bulk tank capacity.
897 tons	P.40 Corn silage capacity purchased.
75.8 tons	P.41 HMEC storage capacity purchased.
79 head	P.42 Cows purchased.
Return to Fixed Resources:	$49,757

TABLE 17

THREE-MAN BUSINESS OPTIMUM

Labor Summary

Month	Labor Hired Hours	Labor Required Hours	Slack Labor Hours
		(Fixed Labor Available, 850 hours per month)	
April	7	857	0
May	300	974	176
June	300	793	357
July	300	889	261
August	300	740	410
September	300	1150	0
October	300	1077	73
November	19	869	0
Dec. - March	0	3400	0

TABLE 18

MARGINAL VALUES OF LIMITING RESOURCES

Three-Man Business Optimum

Resource	Marginal Value
Cropland, Unadilla	$ 82.26 per acre
Cropland, Tioga	161.09 per acre
Cropland, other	63.64 per acre
Winter Labor	5.52 per hour
Standing Hay	27.52 per acre

TABLE 19

PENALTY COST OF INTRODUCING ACTIVITIES NOT IN SOLUTION

Three-Man Business Optimum

Activity		Penalty Cost
P.1 & P.4	Grow Hay on Unadilla	$15.41 & 36.05 per acre
P.2 & P.5	Harvest hay on Unadilla	11.94 & 15.66 per acre
P.3 & P.6	Harvest hay silage on Unadilla	4.25 & 15.41 per acre
P.11	Corn grain on Tioga (12 acres)	1.96 per acre
P.13	Pasture other soil (15 acres)	7.63 per acre
P.16	Corn grain on other soil (12.5 acres)	0.00 per acre
P.19	Buy replacements (40 head)	66.80 per head
P.22	Sell hay (94 tons)	6.30 per ton
P.24	Buy 20% grain	0.32 per cwt.
P.26	Buy 36% supplement	0.23 per cwt.
P.27	Sell corn	17.26 per ton

The three-man business optimum solution has returned $49,757 to fixed resources. If the last man added to the labor force costs $6,000 annually, the return to remaining fixed labor and other resources would equal $43,757. Compare this to the return from the two-man business optimum. Adding a third man to the labor force has increased net returns by approximately $3,600 annually. Returns are $5,000 higher than those obtained in the second optimum solution.

The additional returns are being generated by the substantial increase in cow numbers. Herd size has more than doubled from the basic, no expansion plan. The large dairy herd has forced the use of a very intensive cropping program. The only hay produced on owned land is that required by rotational constraints. Hay must be purchased to meet forage requirements.

Some aspects of this solution are surprising and quite unexpected. Although forage is being purchased, corn grain is still in production. Replacements are still being raised although hay must be purchased to feed them.

The labor summary in Table 17 shows the uneven labor distribution resulting from the heavy corn program. The only months using any significant amount of seasonal labor are May, September and October. The Plan-Now Farm is charged with 300 hours of seasonal labor per month from May through November, and 1220 hours are not used. If the labor supply were completely flexible, labor costs could be reduced by than $2100.

The high marginal values associated with land in Table 17 are further evidence of the crop production intensity in this optimum solution. Adding the third man to the fixed labor force has decreased the marginal value of winter labor. The value of additional standing hay acreage has increased to $27.52, since this is a relative inexpensive source of scarce forage.

The penalty costs of using less intensive crop production processes are large but the penalty for shifting from corn silage to additional acreages of corn grain is relatively small.

If the Plan-Now Farm operator were seriously considering a three-man business, further program adjustments should be made to examine different combinations of resources. The assumption that additional cropland would not be purchased should be relaxed. The purchase or rent of additional cropland appears to be a very profitable alternative and warrants further analysis.

USING LINEAR PROGRAMMING TO DEVELOP A FARM PLAN

The Plan-Now Farm operator was very interested and responsive to the various optimum solutions resulting from this linear programming project. The limitations and estimation problems associated with the linear programming data were explained and considered by the farmer as he studied the results.

The two-man expanded business optimum solution was of particular interest to the farmer. He was already considering a larger dairy facility and had thought about increasing the milking herd to around 120 head. There was little interest in the three-man business solution.

Limitations and Problems

Following are the major limitations and problems considered by the Plan-Now Farm operator as he studied the data and results from the two-man expanded business optimum:

1) Some of the yield estimates are very optimistic and may be high for planning purposes.

2) The coefficients representing machine and labor requirements for crop production may be inaccurate for some processes. Corn fertilization and yield coefficients should be adjusted as the crop rotation becomes more intensive.

3) Linear programming assumes that a 100 cow free-stall barn costs the same per stall as a 200 cow unit and the yield per acre from five acres of corn would be the same as that obtained from 60 acres.

4) The cost estimates used for the expansion activities are average cost data and may not correspond to local prices and building costs.

Conclusions and Decisions

The Plan-Now Farm operator was able to reach the following conclustions:

1) Moving toward an expanded two-man business in a new dairy facility would probably result in a modest increase in farm profits.

2) The largest expense in this plan is the cost of the new facility. If some of the old facilities are incorporated into the plan and if new facilities are purchased over a period of two or more years, costs may be reduced.

3) The seasonal labor bill can be reduced by better distribution of the work load, and a more flexible labor supply.

4) Some production processes and activities have definite economic advantages over others. If input and output data used is reasonably accurate, corn should be considered before hay. Raising replacements will cost less than buying replacements. Specific activities including corn for grain and buying standing hay should be considered regardless of previous biases.

The preceding conclusions led to the following decision on the Plan-Now Farm:

A new free-stall barn and milking facility for approximating 100 cows will be constructed within one year. The old facilities will be adapted for youngstock and dry cows.

The conclusions and decisions made by the Plan-Now farmer are not unique to linear programming. The same decision and many similar conclusions could have been drawn from a conventional budget. The linear programming solution may provide more available information about the value of resources and costs of other activities. Budgeting may be more useful in planning for credit needs and determining a repayment schedule. Budgeting is a more efficient planning tool when one specific plan of action must be compared with another or when there are very few alternatives to be considered.

Linear programming allows consideration of a much wider range of alternatives than is practical with conventional budgeting. The Plan-Now farmer has not considered as many alternatives as would be available on a more diversified operation. However, if we had used conventional budgeting techniques to work out a Plan-Now Farm solution it is likely that only one cropping rotation on each soil type would have been considered. Various labor requirements for activities may have been ignored and alternatives such as raising corn grain, selling hay, and buying standing hay may have been passed off as impractical.

Two major limitations to the widespread use of linear programming as a farm planning tool are the costs associated with the time required to set up a program, and the lack of appropriately trained personnel to conduct the services. The cost of linear programming is directly related to the amount of time required to collect, organize and form the data for the model. The cost of computer time cannot be ignored but is relatively small comparatively. If a large number of similar type farms were to be programmed the time required for each basic plan could be reduced substantially. We would then face the problem of training additional personnnel to conduct farm programming services.

S U M M A R Y

Linear programming was used to find several optimum solutions corresponding to different levels of resource availability on a New York State dairy farm.

The various solutions presented for the Plan-Now Farm illustrate the potential of linear programming as a farm planning tool. Once a basic plan has been developed, an unlimited number of resource combinations can be tested by making relatively small adjustments in the input data. The linear programming solution provides more than the optimum rate of resource use and correct combination of processes. It gives insight into the effect of changing the quantities and use of available resources.

The optimum solution obtained through linear programming is subject to the accuracy of prices used, yield predictions and other coefficient values used in the models. The results are also biased by the restrictions and constraints imposed by the operator and programmer. Programming cannot solve all the problems associated with farm planning. The farm management worker must formulate prices, estimate input-output relationships and must make the decision on what restraints to impose.

Linear programming can be useful in farm management work if its strengths and weakness are understood. The conclusions and decisions reached by the Plan-Now Farm operator have been tempered by the limitations of linear programming and improved by the auxiliary information found in the solution.

Linear programming is not the only or necessarily the best forward planning technique. A complete Plan-Now Farm budget could have been produced faster and with less resources. Conclusions and decisions resulting from a complete budget may be as accurate and as helpful in farm planning as those resulting from linear programming.

APPENDIX I

Selected Activity Budgets

Production processes and activities representing the major parts of the Plan-Now Farm business are presented here. The budget for growing 3-year alfalfa on Unadilla soil can be found in Table 1 on page 10. The summaries of all processes and activities are in Tables 2 and 3 on pages 11 and 12.

Appendix Table A

BUDGET FOR ACTIVITY P2, HARVEST 3-YEAR

Alfalfa Hay, Unadilla Soil

Average Annual Yields, (See Table 1, page 10), 3.5 tons hay equivalent per acre, 3640 lbs. TDN per acre and 840 lbs. digestible protein per acre.

Harvest system: Self propelled windrower with crusher, baler with thrower, wagons, and random piling of bales.

Variable Harvesting Costs, Per acre, and Per year:

Operation	Machine Cost/Hour	Hours	Var. Cost/Acre
S. P. W.	1.67	1.07	$ 1.79
Turn	1.00	1.05	1.05
Bale	1.70	1.08	1.84
Haul and Store	1.64	1.08	1.77
Twine @ $4.66/ton of hay			2.31
		TOTAL	$ 8.76

Labor Requirements:[1/]

Month	Hours Per Acre
June	2.67
July, August, September, and October	0.94

1/ Labor requirements are determined by estimating the time required for each operation during each harvesting period.

Appendix Table B

BUDGET FOR ACTIVITY P8, CORN SILAGE
Unadilla Soil

Average Annual Yield:

16 tons per acre = 9600 lbs. dry matter, 6400 lbs. TDN, 512 lbs. D.P.

Variable Annual Growing and Harvesting Costs:

	Costs Per Acre
Fertilizer (plow down 120-30-90 plus application)	$ 21.30
(plant 8-24-8)	5.25
Lime (.25 tons per acre)	2.63
Seed (.33 bushels per acre)	2.67
Weed Control (atrazine plus linuron)	6.52

Operations:

	Rate Per Hour	Hours	
Plow	$ 1.40	.51	.71
Disk	1.25	.28	.35
Plant	1.10	.25	.28
Spray	.87	.15	.11
Chop	2.25	1.22	3.11
Haul & Store	2.09	1.22	2.55

Total annual variable cost $ 45.48

Labor Requirements:

Month	Hours Per Acre
May	1.19
September	2.65
October	1.33

Appendix Table C

BUDGET FOR ACTIVITY P9, CORN GRAIN

Unadilla Soil

Average Annual Yield: 80 bushels shell corn equivalent or 7000 lbs. HMEC per acre @ 33% moisture, 58% TDN and 4.3% D.P.

Harvest System: Pick, grind and store in silo as high moisture earn corn.

Variable Annual Growing and Harvesting Costs:

			Cost Per Acre
Variable growing costs same as P8, Appendix Table B (fertilizer through spray)			$ 39.82
Operations (additional)	Rate Per Hour	Hours	
Pick and grind	2.57	1.0	2.57
Haul and Store	1.55	1.0	1.55
Total annual variable costs			$ 43.94

Labor Requirement:

Month	Hours Per Acre
May	1.19
October	1.00
November	1.00

Appendix Table D

BUDGET FOR ACTIVITY P17, DAIRY COWS

Annual Milk Sold Per Cow: (Production estimate = 13,000 lbs. 3.5% milk)		12,500 pounds
Annual Revenue Per Cow (Milk Excluded)		
.25 cull cow @ $240	$60.00	
.45 bull calf @ $21	9.45	
.45 heifer calf @ $21	9.45	
Annual Variable Cost Per Cow:		$78.90
Breeding Fees	$ 8.00	
Veterinary & Medicine	10.00	
Bedding	4.00	
DHIC	8.80	
Milk House Supplies	9.60	
Other dairy expenses	4.90	
Cow Insurance	2.00	
Death Loss	11.85	
Electricity	5.75	
		$67.90
Net Return Over Variable Costs:		$11.00

Feed Requirements Per Cow:

TDN from forage, 6000 lbs.[1/]
TDN from grain 3550 lbs. Total 9550 lbs.[1/] TDN
Digestible protein 1160 lbs.

Labor Requirement per cow (man hours per cow month):

Present facilities:		Free-Stall Barn:	
September through April	6.1 hrs.	October through May	4.0 hrs.
May through August	5.2 hrs.	June through September	2.9 hrs.

1/ Coefficients used after first solution.

Appendix Table E

BUDGET FOR ACTIVITY P18, RAISE REPLACEMENTS
To 27.5 Months of Age

Variable Cost Per Head:

Heifer Calf	$50.00
Milk substitute	10.00
Veterinary & Medicine	2.00
Other livestock expense 1/	1.05
Share of bull	3.00
Death Loss (15%)	3.15
Electricity	2.00
Insurance	1.80
TOTAL	$73.00

Feed Requirement Per Head:

1600 lbs. of 15% total protein grain = 220 lbs. of D.P. and 1120 lbs. of TDN.

4.0 tons of hay equivalent = 4000 lbs. TDN and 840 lbs. digestible protein.

Labor Requirements Per Head:

June through September	1.25 hours	x	2.3 years	=	2.9 hrs/month
October through May	1.75 hours	x	2.3 years	=	4.0 hrs/month

1/ No registration fees included.

Appendix Table F

BUDGET FOR ACTIVITY P25, BUY 27%

Total Protein Concentrate

Use: Concentrate purchased and mixed with high moisture ear corn to supply 3550 pounds TDN per cow per year.

Mix:	Pounds of 27%	Pounds of HMEC	Total
Weight	36.8	63.2	100
TDN/cwt.	24.4	36.7	62.1
D.P./cwt.	7.9	2.7	10.6

Variable Cost Per 100 Pounds of Grain Fed:

27% concentrate @ $87/ton = $1.60 per 36.8 pounds
Handling HMEC & mixing grain = .02
TOTAL 1.62 per cwt.

Labor Requirement:

Mixing and handling; 0.01 hours per month