June 1989 A.E. Res. 89-10

MANAGEMENT STRATEGIES TO IMPROVE PROFITABILITY ON LIMITED RESOURCE DAIRY FARMS:

A LINEAR PROGRAMMING ANALYSIS

by
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ABSTRACT

A set of limited resource dairy farms were identified: those operating with stanchion or tie stall barns, using bucket or pipeline milking systems and producing no corn grain but only forage crops for dairy feed. Alternative strategies for increasing labor and management income per operator that required only modest amounts of additional capital were investigated. The most promising strategies based on linear programming analyses were: (1) increasing milk production per cow by improved balancing of rations, (2) improving the quantity of forage crops produced per acre, and (3) increasing the quality of forages harvested by advancing the time of cutting.

MANAGEMENT STRATEGIES TO IMPROVE PROFITABILITY ON LIMITED RESOURCE DAIRY FARMS: A LINEAR PROGRAMMING ANALYSIS[1]

Summary of Study Results

Many farms in New York State have soils which are unsuitable for growing grain, have bucket or pipeline milking systems, and cannot increase herd size without significant capital investments in housing and equipment. Farms in this category tend to have average to below average returns to labor and management income, and their future profitability and survival are likely to face increasing pressure from declining milk prices, increased production costs, and the adoption of new technology by the dairy industry.

The objective of this study is to identify and test feasible management strategies which might be used to improve the profitability of limited-resource farms in New York State. These are farms which do not harvest corn for grain, have a tie-stall or stanchion barn, and do not have a milking parlor. Linear programming was used to test alternative management strategies including increased production per cow, increased yields and quality of hay-crop forages, increased storage for corn silage, and shorter rotations for hay-crop forages.

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[1]This report summarizes important sections of Murray-Prior's, M.S. thesis, "Management Strategies For Improving Profitability of Average Resource Dairy Farms in New York State," Cornell University, May 1989. The authors especially appreciate the careful review of this publication and the thesis by R. A. Milligan, a member of Murray-Prior's graduate committee. Faculty in agronomy, animal science and agricultural engineering assisted in developing budgets and reviewing coefficients used in the linear programming models. Special thanks to S. Smith, W. Knoblauch and L. Putnam for assistance with the DFBS database, helpful criticism during the project, and careful review of this manuscript. Murray-Prior has returned to Australia to continue his professional career.

A companion publication providing the individual crop and livestock budgets for each of the activities included in the linear programming analysis is issued as Murray-Prior, Roy, "Budgeting Data for Average Resource Dairy Farms, New York." Included are crop budgets by type of equipment and labor requirements; nutritional requirements by production level; nutrient content of forages for each crop budget; and detailed data used in building the linear programming models.

Two major categories of Limited Resource Farms were established: (1) farms whose largest tractor is 60 horsepower, and which have a bucket milking system (SB), and (2) farms whose largest tractor is 100 horsepower, and which have a pipeline milking system (LP). SB farms have 130 tillable acres, 37 cows, and cows producing at 10,750 pounds per cow, while the LP farms have 200 acres of tillable land, 74 cows, and cows producing at 14,000 pounds per cow. Three types of SB farm and two types of LP farm are examined according to their ability to produce corn silage and hay-crop silage. The objective functions of the linear programming models maximize returns over variable costs. Adjusted labor and management income per operator (net income) is calculated from this as a measure of profitability by subtracting fixed costs, including a fixed return of five percent on the total value of assets.

The linear programming analyses indicated that each increase in milk sales of 1,000 pounds of milk per cow increases net income by about $2,500 for the SB farms and $4,000 for the LP farms. These increases in production as a result of balancing rations require increased concentrate purchases which improve the energy and protein content of the total ration. Increasing forage quality and quantity both increase profitability individually but to a lesser degree. If farms are already feeding relatively high levels of concentrates, then significant improvements in profitability through increased production per cow will require improvements in the quality of the forage. Increasing storage capacity for corn silage, and decreasing the length of the rotation for the hay-crop forages do not result in major increases in profitability. The linear programming analyses also show that farms with low profitability, and low productivity per cow will gain more from improving the productivity of the present herd before expanding herd size.

Introduction

The purpose of this study is to examine alternative management strategies which might be used to improve the profitability of limited-resource dairy farms in New York State. Limited-resource dairy farms are defined for the purposes of this study as: (1) obtaining 90 percent or more of gross income from the dairy enterprise, (2) harvesting no corn for grain, and (3) having a stanchion or tie stall barn with pipeline, dumping station, or bucket and carry milking systems. Approximately 51 percent of all dairy farms in the state can be categorized as ARFs according to data from the Farm Management and Energy

Survey[2] (FMES). These farms have an average herd size of about 60 cows.

Data from the 1986 and 1987 Dairy Farm Business Summaries (Smith, Knoblauch and Putnam) indicate farms of this size and type on average obtain low returns for their labor and management. Since the land being used by these farmers has limited alternative uses in agriculture, operators who wish to remain in farming need to improve their management, with consequent increases in productivity and efficiency, to compete effectively in dairy farming.

Objectives

The specific objectives of this study are to:

(1) Evaluate alternative short-term management strategies requiring small amounts of new capital to increase profitability on limited-resource dairy farms. Specific strategies include methods of increasing milk yield per cow, increasing forage yields, improving forage quality, increasing corn silage production and improving cost controls.

(2) Determine the sensitivity of these strategies and their impact when there are changes in the price of milk or purchased concentrates.

Profitability in this study is defined as return to adjusted labor and management income per operator, which is labor and management income per operator adjusted for a standard charge for the use of equity and borrowed capital.

It is hypothesized that increasing milk yields per cow is an important strategy for increasing profitability. Increases in forage yields, forage quality, and production of corn silage are also expected to improve profitability. Forage quality should prove an important determinant of purchased feed costs per cow, and improved quality should decrease these costs through decreasing concentrate requirements. Management systems which rely on baled hay, limited silage and no corn grain will be appropriate when soil resources are quite limited.

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[2]The 1987 Farm Management and Energy Survey was conducted by the Departments of Agricultural Economics and Agricultural Engineering at Cornell University, and carried out by the New York Agricultural Statistics Service. Funding for the survey was provided by the Niagara Mohawk Corporation.

Research Procedure

Five representative limited-resource farm situations were constructed based on data from the 1987 FMES. A linear programming model was constructed for each representative farm situation. The objective function maximized return over variable expenses. Activities included in the model were cow and heifer production, crop production, sale and purchase of crops and livestock replacements, milk sales, land, hired labor, and livestock feeding activities. Enterprise budgets were developed to determine receipts, variable expenses, and fixed expenses for the various enterprises. Land availability and use, labor, cow numbers, and rations were included as constraints. The LP88 program (Eastern Software Products) was used to derive the initial optimal solutions. Fixed costs, other than operators' labor and management, were deducted to allow calculation of adjusted labor and management income per operator.

The models were then adjusted to take account of the various management strategies and their effects on net income and on the optimal activities in solution.

Construction of Representative Farms and Linear Programming Model

Development of Representative Farms

Data from the 1987 Farm Management and Energy Survey (FMES) provided the basis for constructing the representative farms. The farms selected for study were primarily dairy enterprises, with tie stall or stanchion barns, and without a milking parlor. In addition, only farms which had not harvested corn for grain were included to obtain farms with soils which are used primarily for forage production.

Initially, data from the FMES survey meeting the above criteria were categorized according to region, milking system, and size of largest tractor. Because the differences among farms within regions was greater than between regions, the regional division was dropped. This left four categories of farms: large tractor-pipeline (LP), small tractor-pipeline (SP), large tractor-bucket milking (LB), and small tractor-bucket milking (SB).

For the purposes of this study, it was decided to concentrate on two categories of farm, large tractor-pipeline (LP), and small tractor-bucket (SB). These two categories contain the largest numbers of farms, and also represent the opposite ends of the spectrum of dairy and cropping technologies examined in this study. The other two categories were intermediate to these two. Data obtained from sorting the FMES data were used as a basis for developing these representative farms.

The two classes of farm (SB and LP) are defined in terms of: acres of tillable and non tillable land, barn capacity, cow and heifer numbers, largest tractor size, and labor. The farms are assumed to operate with average to below average levels of management which limits their ability to make dramatic changes in productivity. Particular emphasis is placed on using cropping management levels consistent with information obtained from the FMES and DFBS surveys and with suggestions of individuals familiar with New York dairy farms of this type. Table 1 summarizes the average resource characteristics of these farms.

Table 1. CHARACTERISTICS OF LARGE TRACTOR-PIPELINE AND SMALL TRACTOR-BUCKET FARMS
Farm Management and Energy Survey Data, New York, 1986

Characteristic	Representative Farm	
	Large pipeline	Small bucket
Land, acres		
Total land	400	280
Total crop land	220	130
Soil group 3	65	32.5
Soil group 6	155	97.5
Crop land rented	94	63
Non-tillable pasture	80	55
Livestock		
Milk cow number	74	37
Heifer/cow ratio[a]	0.8	0.76
Milk sold, lbs./cow	14,000	10,750
Cropping equipment		
Largest tractor, HP	100	60
Labor and management[a]		
Operator, family and full-time hired, hours/month	644	397
Number of operators	1.25	1

Footnotes:

a. From DFBS 1986 for farms with similar average numbers of cows.

Acres of total land, total crop land, and crop land rented are based on averages and typical situations from the FMES. Crop land is further divided into two soil productivity groups. Soil productivity groups are used by the Division of Equalization and Assessment and are based on the potential crop yield of predominant soils and maximum years of corn in a rotation. The area of non-tillable pasture land was estimated by adjusting the non-tillable land from the FMES survey for the proportion of non-tillable land on farms of similar size in the 1986 DFBS[3].

Average cow numbers are 37 for the SB farms and 74 for the LP farms. The heifer/cow ratios are set at 0.76 for the SB farms and 0.80 for the LP farms based on the average of herds of similar size in the 1986 DFBS. Cows in the SB farms are assumed to be housed in a two-story, stanchion barn with a bucket milking system. The LP farms are assumed to have a two story, stanchion barn with a pipeline milking system. Both are assumed to have tie stalls, gutter cleaners, and rely on daily manure spreading. Hay is stored in the loft. Both have upright, concrete, stave silos for corn silage, and smaller, concrete, horizontal silos to store hay-crop silage[4].

Equipment complements for each farm were developed assuming a basic tractor size. This was 60 horsepower for SB, and 100 horsepower for the LP farms, based on averages from the FMES survey. Where appropriate the farms are assumed to have sufficient equipment to grow and harvest corn silage, hay-crop silage and hay.

Permanent labor available is set at 397 hours per month, and 644 hours per month respectively, for the SB and LP farms. These are derived from Smith et al. (1987) for farms of similar herd size. Additional seasonal labor can be hired at $5.00 per hour, if it is profitable to do so. One full time operator is assumed for the SB farm, and 1.25 full time operators for the LP farm (Smith et al., 1987).

Input and output prices used in the study are presented in Table 2. Where possible the prices are actual 1986 prices, although in some cases adjustments are made using indices from the New York Economic Handbook.

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[3] DFBS is the annual Dairy Farm Management Business Summary published by the Department of Agricultural Economics.

[4] A small horizontal silo is probably not very common except to handle surplus feed. A recent alternative to the horizontal silo is the plastic storage bag for silage. Annual costs are higher but losses of silage are lower. On some farms hay-crop silage and corn silage might both be stored in the tower silo, but then only one could be fed at a time.

Table 2. INPUT AND OUTPUT PRICES
New York Dairy Farms, 1986

Item	Unit	Price, Value or Cost Selling	Buying
Livestock			
Replacement heifers[a]	heifer		$755.00
Cull cows[a]	cwt.	$33.60	
Bull calves[a]	cwt.	$57.80	
Forage[b]			
Hay - Alfalfa/grass	ton		$ 78.37
Hay - Trefoil/grass	ton		$ 69.27
Feed			
Corn - ground, shelled[c]	cwt.		$ 5.70
Soybean meal (44%)[a]	cwt.		$ 11.60
Mixed dairy feed[a]	ton		$162.90
Milk replacer[d]	cwt.		$ 47.00
Salt[a]	cwt.		$ 8.60
Dicalcium phosphate[c]	cwt.		$ 17.00
Limestone[c]	cwt.		$ 2.00
Seed			
Alfalfa[e]	lb.		$ 2.90
Timothy[e]	lb.		$ 0.80
Trefoil[f]	lb.		$ 4.04
Corn[e]	80K		$ 60.00
Fertilizer[e]			
N	lb.		$ 0.24
P	lb.		$ 0.22
K	lb.		$ 0.14
Custom spreading[g]	ac.		$ 5.00
Lime[e]	ton		$ 25.00
Chemicals			
Atrazine 4L[e]	gl.		$ 8.45
Crop Oil[f]	gl.		$ 10.40
Furadan[e]	lb.		$ 1.38
Methoxychlor 2E[e]	gl.		$ 11.88
Premerge[e]	gl.		$ 13.00
Sutan & 6.7E[f]	gl.		$ 22.47
Labor[e]			
Seasonal	hour		$ 5.00
Capital[e]			12%
Fuel[e]			
Diesel	gl.		$ 1.10
Gasoline	gl.		$ 1.00

Footnotes to Table 2:

a. New York Agricultural Statistics.
b. New York Agricultural Statistics adjusted for quality differentials as reported in Twentyman and Whitaker.
c. Knoblauch, Chase, and Lowry, 1986.
d. OSU, 1987.
e. Snyder and Lazarus, 1986.
f. Adjusted from Twentyman and Whitaker using indices from the New York Economic Handbook, 1988.
g. Snyder, 1988.

Forage Crops

Corn silage can be grown on both soil groups. An alfalfa-timothy mixture is assumed to be grown on soil group three land in rotation with corn for silage. The soil group six land is divided into two types: rented and owned. Corn silage is grown in rotation with an alfalfa-trefoil-timothy mixture on the owned land. The rented land can only be used for harvest of grass hay. Harvest, storage, and feeding losses for all crops are provided in Tables 4, 6, and 11.

Corn Silage Production

Initially corn silage yields were adjusted to reflect yields reported in the FMES and DFBS surveys. The differential in yields between soil groups is proportional to that given for these soils by W.S. Reid and reported in Twentyman and Whitaker. Yields on the SB farms are 11.5 t/ac on soil group three and 8.1 t/ac on soil group six. For the LP farms the yields are 15.3 t/ac, and 10.7 t/ac for soil groups three and six respectively.

For each soil group and farm a calendar of operations is established. The characteristics of the equipment complement for each farm are then used to calculate the tractor hours and equipment costs for each operation using a Lotus template (Lazarus, 1986). Equipment speed and efficiency are assumed to be the same on both soil groups. Although lower speeds and efficiency might be expected on soil group six because of slope and rock conditions, lower yields would tend to offset this. Equipment speed and costs vary between farms because of the differing tractor and equipment sizes. Timing of operations on the soil groups is differentiated to reflect farming practices, and the interaction of weather and soil group. Labor hours per acre are derived from tractor hours calculated from the Lotus template, based on the conversion factors used by Partenheimer and Knievel.

Alfalfa-Timothy Production

An alfalfa-timothy mixture is established as the legume forage grown on soil group three for both farms. Initially it is assumed to be grown in rotation with corn and to have a five year life. For the purposes of the model, this is divided into three periods: the establishment year, years two and three, and years four and five. The establishment year is assumed to be cut only once, and to yield 50 percent of the yield in year two. In years two and three, two and one half cuts are assumed at maximum yield levels. Two cuts are assumed for years four and five; yields are decreased, and the proportion of grass is increased. The representative farms are assumed to ensile the first cutting and to make hay from other cuttings.

Table 3. ANNUAL VARIABLE COSTS PER ACRE FOR FORAGE CROPS
Limited Resource Farms, New York, 1986

Crop	Small bucket	Large pipeline
	per acre	
Corn silage (3)	$144	$137
Corn silage (6)	127	120
Alfalfa-timothy (3)		
Hay - establishment year	181	180
Hay/HCS - years 2-3	66	68
Hay/HCS - years 4-5	46	48
Hay - years 2-3	67	69
Hay - years 4-5	46	48
Trefoil-alfalfa-timothy (6)		
Hay - establishment year	178	179
Hay - years 2-4	50	51
Hay - years 5-7	30	31
Unimproved pasture hay	13	13
Grazing	6	6

Calendars of operations are prepared for each period and soil group. These are combined with equipment complements to calculate tractor hours, labor hours, and equipment costs as described for corn silage. Speed and efficiency of operation are once again assumed to be the same for the two soil groups, although operations are assigned different time periods to reflect the various yield and quality potentials, as well as operational characteristics of the soils.

Yields obtained from the FMES and DFBS data are used to provide upper guidelines in developing a system to estimate forage yields on the farms. A yield of 3.2 tons per acre of dry matter before harvest is assumed for three cuts of alfalfa-timothy in the first full year. The third cut is assumed to be harvested only fifty percent of the time. Table 4 outlines the estimates for yields obtained from these calculations in the year after establishment.

Table 4. ESTIMATES OF HARVESTED YIELDS, ALFALFA-TIMOTHY ON SOIL GROUP THREE IN FIRST FULL YEAR FOR ALL HAY AND COMBINED HAY AND SILAGE

Cut	Time of cut	Percent of total yield	Standing yield DM	Harvested yield[a] Hay	HCS/Hay
				tons per acre	
1	June	44	1.41	1.28	3.34
2	July	30	0.96	0.87	0.87
3	August	26	0.83	0.76	0.76
Total			3.20		

a. Harvested yield assumes losses of 21 percent for hay and 5 percent for hay-crop silage. Yield is of wet material at 85 percent DM for hay and 40 percent DM for hay-crop silage. The HCS/hay yields assume the first cut is to silage and the second and third are to hay.

Estimates for other years are then calculated based on yields in the first year. In years three and four, two cuts are assumed, as well as a decline in yield. Table 5 shows the yields of hay alone, and hay and hay-crop silage for each year, plus the average for each period.

Table 5. HARVESTED YIELDS OF ALFALFA-TIMOTHY ON SOIL GROUP THREE
Limited Resource Farms, New York, 1986

Year	Product	Percent of 2nd year	Hay Wet	Hay DM	HCS/Hay Wet	HCS/Hay DM
			tons per acre			
Establish	Hay	50%	1.45	1.26	1.45	1.26
2nd	Hay	100%	2.53	2.20	1.25	1.09
	Silage				3.34	1.34
3rd	Hay	100%	2.53	2.20	1.25	1.09
	Silage				3.34	1.34
4th	Hay	80%	2.02	1.76	1.00	0.87
	Silage				2.68	1.07
5th	Hay	64%	1.62	1.41	0.80	0.70
	Silage				2.14	0.86
Average	Hay		2.53		1.25	
Years 2&3	Silage				3.34	
	Total DM			2.20		2.42
Average	Hay		1.82		0.90	
Years 4&5	Silage				2.41	
	Total DM			1.58		1.75

Trefoil-Alfalfa-Timothy

A trefoil-alfalfa-timothy mixture is assumed to be grown for the grass-legume forage on soil group six land owned by the farm. It is assumed to be grown in rotation with the corn and to have a seven year life. This is divided into three periods: the establishment year, years two, three and four, and years five, six and seven. The establishment year is assumed to be cut once, and to yield 50 percent of year two. Years two, three, and four are assumed to be cut twice, while years five, six, and seven are cut only once. All cuts are to hay. Yields are decreased over time and the proportion of grass to legume increased.

Similar principles are used in estimating yields as are used for the alfalfa-timothy mixtures on soil group three. A yield of 2.6 tons per acre of dry matter before harvest for two cuts in the second year is assumed (Reid and Seeney). The percentage of total yield available to be harvested in each cut are then estimated (Rayburn; Crispell). Tables 6 and 7 contain the estimates of yields obtained from these calculations.

Table 6. HARVESTED YIELDS OF TREFOIL-ALFALFA-TIMOTHY HAY ON SOIL GROUP SIX IN FIRST FULL YEAR

Cut	Time of cut	Percent of total yield	Standing yield DM	Harvested[a] yield hay
			tons per acre	
1	June	65	1.69	1.53
2	August	35	0.91	0.83
Total			2.60	

a. Harvested yield assumes losses of 21 percent for hay. Yield is of wet material at 85 percent DM.

Table 7. HARVESTED YIELDS OF TREFOIL-ALFALFA-TIMOTHY ON SOIL GROUP SIX Limited Resource Farms, New York, 1986

Year	Product	Percent of 2nd Year	Hay Wet	Hay DM
			tons per acre	
Establishment	Hay	50%	1.18	1.03
2nd	Hay	100%	2.36	2.05
3rd	Hay	90%	2.12	1.85
4th	Hay	72%	1.70	1.48
5th	Hay	50%	1.40	1.22
6th	Hay	50%	1.18	1.03
7th	Hay	50%	1.18	1.03
Average Years 2-4	Hay		2.06	1.79
Average Years 5-7	Hay		1.25	1.09

Rented Grass Hay

A proportion of the rented land is assumed to be cut once per year for grass hay. Because of the nature of the rental agreement, this is the only option allowed on this land. The grass is assumed to have been sown many years ago, and no fertilizer or other inputs are used. Yield is 1.15 tons per acre of hay at 88 percent dry matter (Rayburn).

Pasture Grazing

Apart from cropland, some unimproved pasture which can be used for grazing dry stock is included on all farms. This land is considered to be unsuitable for tillage because of slope, drainage or other factors. It is assumed to be poorly fenced, not fertilized, and to be clipped once per year. Yield is 3.57 wet tons per acre of clover and grass, at 28 percent dry matter (Twentyman and Whitaker). Grazing losses are assumed to be high (25 percent) because of minimum management.

Livestock

Nutritional Requirements

Annual feed requirements for milking cows, dry cows, and replacement heifers are calculated by balancing rations for: maximum dry matter intake, minimum net energy, minimum crude protein, and minimum acid detergent fiber. Cows are assumed to weigh 1,250 pounds. The base level milk sales assumed are 10,750 pounds per year for the SB farms and 14,000 pounds per year for the LP farms, both with a 3.7 percent butterfat test. Reductions from home consumption, feed, and waste are estimated to be 1.5 percent (Johnson; Knoblauch and Milligan, 1977). This gives production levels of 10,914 pounds and 14,213 pounds, respectively. Cows are further assumed to have a 13-month calving interval (336 days in milk and 60 days dry).

A lactation curve for each level of production is developed. Since the cows are housed in tie stall or stanchion barns, it is possible for farmers to provide feed for the cows according to their individual needs. This is difficult to model, and hence the simplifying assumption is made to divide the cows into three production groups: high (H), medium (M), and low (L), plus a dry group (D). Cows are placed in each production group for 112 days, and spend 60 days dry. Because a 13-month lactation period is assumed, the yearly production levels are adjusted by a factor of 396/365. Weekly production levels are calculated in terms of pounds of milk per day using the Wood's equation (1979, 1980). Wood's equation is based on a 305 day (44 weeks) production period. Therefore, production using the Wood's equation is adjust to a level over 48 weeks. The equation is then used to calculate production levels for each week during the 48-week production period. These are averaged for each of the three production periods to give average production in pounds per day per cow. The dry matter, energy, crude protein, and acid detergent fiber requirements calculated using these assumptions are multiplied by 365/396 to reduce them to annual requirements.

Daily nutrient requirements for lactating and dry cows are calculated using formulas from Least-Cost Balanced Dairy Rations (Milligan, Chase, Sniffen, and Knoblauch). Requirements are increased by seven percent to take account of the needs of first and second calf heifers for extra feed to enable them to grow to full size (Partenheimer and Knievel).

In practice, cows are also likely to lose weight in the early period of lactation, and regain it later in the lactation. To take account of this, a maximum of one-fourth of high period maintenance energy requirements are allowed to be shifted to the low period (Partenheimer and Knievel). Each megacalorie of energy shifted in this way is assumed to require 1.05 megacalories to replace it (NRC). This is accommodated within the constraints of the model, and hence occurred only when profitable.

A part of this study involves examining the effect of increased production per cow above the base levels already discussed. Cows fed at higher production levels require more nutrients. However, at higher levels of feeding, cows are not as efficient at obtaining energy from feed as they are at lower levels (Milligan, et. al., 1981, Partenheimer and Knievel). Hence, it takes more units of energy for additional milk from a higher producing cow than a lower producing cow. To make such calculations requires a large number of extra activities in an LP format. This situation is accommodated by increasing the energy requirements of the higher producing cows, rather than adjusting energy levels of the feed. The adjusted requirement is calculated using the formula: Adjusted requirement = Daily requirement/(1-Change in MI*DF). MI is the maintenance increment. It is calculated as: Daily requirement/Maintenance requirement - 1. The change in MI is the difference between the maintenance increment at the higher level of production, and the maintenance increment at the base level of production used for each farm. DF, or discount factor, is the percentage decrease in the energy available from feed per unit of maintenance increment. This discount factor varies with the type of feed (van Soest, Fadel, and Sniffen), however, since this cannot be fully accommodated with this simplification, a standard rate of four percent is used (Johnson).

A minimum allowable level of adjusted acid detergent fiber is set at 15 percent of dry matter intake for the cows (Milligan, et. al., 1981).

Replacement heifers are assumed to take 30 months to reach their initial calving weight of 1,100 pounds. Their feed requirements are calculated in three groups: birth to three months, three to 12 months, and 12 to 30 months. Feed for calves less than three months old is included as a cost in the heifer budgets. Heifers are assumed to be 200 pounds at three months, and to grow to 550 pounds at 12 months. Nutrient requirements are based on the average weight during each period, and the rate of gain (NRC).

Pasture grazing is limited to dry cows and replacement heifers with consumption of pasture limited to 50 percent of their total dry matter requirements.

Receipts and Expenses

Annual receipts, expenses and labor requirements for dairy cows on the small-bucket, and large-pipeline farms are presented in Tables 8 and 9. These are for cows from which 10,750 and 14,000 pounds of milk, respectively, are sold annually. The milk prices are net of marketing costs and are based on averages for farms of similar size from the DFBS for 1986. Costs are developed from various sources and are adjusted to reflect production levels.

Table 8. MILKING COW INCOME AND VARIABLE EXPENSES FOR SMALL TRACTOR-BUCKET FARM
Limited Resource Farm, New York, 1986

	Unit	Quantity	Price	Value
INCOME				
Milk sales[a]	cwt.	107.5	$11.40	$1,225.50
Cull cow sales[b]	cwt.	3.5	$33.50	$117.25
Calf sales[c]	cwt.	0.415	$57.80	$23.99
Gross Income				$1,366.74
VARIABLE EXPENSES				
Power and machinery[d]				
Repairs & maintenance				$40.20
Fuel, oil & grease				$6.75
Building, feed storage & equipment[e]				
Repairs & maintenance				$26.00
Livestock				
Bedding[f]	ton	0.75	$10.00	$7.50
Breeding fees[g]				$24.10
Veterinary & medicine[g]				$22.80
Supplies and other[g]				$50.60
Utilities[g]				$57.00
Dicalcium phosphate[h]	cwt.	0.37	$17.00	$6.29
Salt[h]	cwt.	0.45	$8.60	$3.87
Interest on operating expenses[i]	$	245.11	0.01	$2.45
TOTAL VARIABLE EXPENSES				**$247.56**
Labor requirements - Hrs/Month/Cow			6.5	

Footnotes:

a. FMES data; price is net of marketing costs.
b. Assumes 28% culls and 1250 pound bodyweight.
c. Assumes 50% bull calves, a 10% death loss (Partenheimer).
d. Adjusted from Nott S.B. et.al. 1986.
e. Based on DFBS for farms with similar herd average sizes.
f. Partenheimer and Knievel, 1983.
g. Adjusted from DFBS.
h. Amount required from Knoblauch et.al. 1978.
i. Interest on operating expenses for 1 month at 12%.

Table 9. MILKING COW INCOME AND VARIABLE EXPENSES FOR LARGE TRACTOR-PIPELINE FARM
Limited Resource Farm, New York, 1986

	Unit	Quantity	Price	Value
INCOME				
Milk sales[a]	cwt.	140	$11.70	$1,638.00
Cull cow sales[b]	cwt.	3.5	$33.50	$117.25
Calf sales[c]	cwt.	0.415	$57.80	$23.99
Gross income				$1,779.24
VARIABLE EXPENSES				
Power and machinery[d]				
Repairs & maintenance				$40.20
Fuel, oil & grease				$6.75
Building, feed storage & equipment[e]				
Repairs & maintenance				$16.50
Livestock				
Bedding[f]	ton	0.75	$10.00	$7.50
Breeding fees[g]				$21.10
Veterinary & medicine[g]				$29.80
Supplies and other[g]				$65.60
Utilities[g]				$62.00
Dicalcium phosphate[h]	cwt.	0.37	$17.00	$6.29
Salt[h]	cwt.	0.45	$8.60	$3.87
Interest on operating expenses[i]	$	259.61	0.01	$2.60
TOTAL VARIABLE EXPENSES				**$262.21**
Labor requirements - Hrs/Month/Cow			5.8	

Footnotes:

a. FMES data; price is net of marketing costs.
b. Assumes 28% culls and 1250 pound bodyweight.
c. Assumes 50% bull calves, a 10% death loss (Partenheimer).
d. Adjusted from Nott S.B. et.al. 1986.
e. Based on DFBS for farms with similar herd average sizes.
f. Partenheimer and Knievel, 1983.
g. Adjusted from DFBS.
h. Amount required from Knoblauch et.al. 1978.
i. Interest on operating expenses for 1 month at 12%.

The annual expenses and labor requirements for raising a heifer from birth to freshening is shown in Table 10. These costs are assumed to be the same for both farms.

Table 10. REPLACEMENT HEIFER ANNUAL VARIABLE EXPENSES FROM BIRTH TO FRESHENING

	Unit	Quantity	Price	Value
INCOME				
Cull heifers[a]	head	0.06	$368.50	$22.11
VARIABLE EXPENSES				
Power and machinery[b]				
Repair & maintenance				$4.80
Fuel, oil, & grease				$2.25
Building, feed storage, & equipment[c]				
Repairs & maintenance				$8.50
Livestock				
Bedding[d]	ton	0.50	$10.00	$5.00
Breeding fees[e]	head			$9.20
Veterinary & medicine[e]	head			$7.20
Supplies[e]	head			$14.40
Utilities[e]	head			$8.00
Calf starter[f]	cwt.	1.20	$8.00	$9.60
Milk replacer[f]	cwt.	0.16	$47.00	$7.52
Trace mineral salt[f]	cwt.	0.20	$8.60	$1.72
Interest on operating expenses[h]	$	78.19	0.01	$0.78
TOTAL VARIABLE EXPENSES				**$78.97**
Labor requirements - Hrs/heifer/month		1.04		

Footnotes:

a. Six percent of replacement heifers culled on entering the herd, weight 1100 pounds, at $33.50 per hundredweight.
b. Adjusted from Nott S.B. et.al. 1986.
c. From Nott S.B. et.al. adjusted from 30 month to 12 months.
d. Bedding requirement from Partenheimer & Knievel, 1983.
e. Based on Nott S.B. et.al. adjusted to 12 month period.
f. Taken from Partenheimer & Knievel, 1983.
g. One month at 12%.

Labor

Labor requirements are based on Hoglund who estimates labor requirements for cows (including raising replacements) to be 85 hours and 77 hours, respectively, for 40-cow and 75-cow dairies with stanchion barns. The 40-cow operation assumes a bucket milking system, while the 75-cow operation assumes a pipeline system. For the 40-cow operation, 27 cows are milked per hour. For the pipeline system, 34 cows per hour are milked. This implies three hours less per cow per year for a 40-cow pipeline system. The hours for a pipeline dairy with 40 cows are therefore

82 per year. In this study, cow and heifer labor requirements are separated. Wackernagel, Milligan, Knoblauch, Partenheimer and Knievel use 25 hours for raising a heifer from birth to freshening in 24 months. This is an average of 12.5 hours per heifer per year. Assuming Hoglund's calculations include heifers at 60 percent of cow numbers, this implies the heifer labor requirement is 12.5*0.6, or 7.5 hours per heifer per year. Therefore, at 40 cows and 75 cows, the per cow labor requirements for pipeline dairies are 74.5 hours and 69.5 hours, respectively. These requirements are then adjusted for the cow numbers and milking systems assumed for the SB and LP farms. Monthly labor requirements for cows and heifers are presented with their respective budgets.

Nutrient Content of Feeds

Farm-produced forages, purchased corn grain, and soybean meal are used to meet the nutrient requirements of the cows and heifers in this study. Farm-produced feeds include: corn silage, alfalfa-timothy hay or hay-crop silage, trefoil-alfalfa-timothy hay, grass hay, and grazed pasture. Both the alfalfa-timothy and trefoil-alfalfa-timothy forages are divided into separate feeds because of different cutting times and grass mixtures.

Nutrient contents of the farm-produced and purchased feeds are shown in Table 11. The levels for the purchased feeds and corn silage are taken from Milligan, et al. (1981), while the values for grass hay and grazed pasture are adapted from NRC and Rayburn.

The nutrient levels for the alfalfa-timothy and trefoil-alfalfa-timothy mixtures are adapted from a computer simulation model for predicting alfalfa forage quality developed by Fick and Rao. The program estimates alfalfa quality as a function of harvest date and corrects for harvest losses. Weather and time are used to predict quality using historical weather data.

Weather data from Norwich, New York for 1970 to 1987 are used, and quality estimates obtained for percent total digestible nutrients (TDN), crude protein (CP), and acid detergent fiber (ADF). Losses of 21 and 5 percent, respectively, are assumed for hay and hay-crop silage (Partenheimer and Knievel). The cutting times and frequencies are those outlined earlier for the various management strategies for alfalfa-timothy and trefoil-alfalfa-timothy.

The TDN levels for all feeds are converted to the net energy levels for lactation (NEl), maintenance (NEm), and gain (NEg) used in the linear programming models. Energy of feeds for milking and dry cows is calculated in terms of NEl, while energy for replacement heifers is in terms of NEm and NEg.

Table 11. NUTRIENT CONTENT OF FARM PRODUCED AND PURCHASED FEEDS
Limited Resource Farms, New York, 1986

Feed	Dry Matter	TDN	Protein	ADF	Discount Factor
			percentage		
Purchased					
Corn grain[a]	89	88	10.0	0.5	3.3
Soybean meal[a]	90	81	48.9	2.0	5.1
Alfalfa-timothy hay[b]	87	58	17.3	33.9	3.5
Trefoil-timothy hay[b]	87	55	13.6	40.5	4.0
Farm produced					
Corn silage[a]	33	70	8.5	28.0	5.3
Alfalfa-timothy HCS(1)[b]	40	61	15.9	31.4	3.5
Alfalfa-timothy hay(1)[b]	87	58	17.3	33.9	3.5
Alfalfa-timothy HCS(2)[b]	40	55	13.9	36.6	3.5
Alfalfa-timothy hay(2)[b]	87	50	14.0	40.5	3.5
Trefoil- timothy hay(1)[b]	87	50	13.6	40.5	4.0
Trefoil-timothy hay(2)[b]	87	48	10.3	45.6	4.0
Grass hay[c,d]	88	48	7.9	45.6	7.0
Grazed pasture[c,d]	28	65	14.8	33.0	7.0

Sources:

a. Milligan et.al. 1981.
b. Calculated using Cornell AQP, Fick and Rao, 1988.
c. NRC p.48 (mid-bloom).
d. Rayburn, E. 1987.

To calculate NEl, the TDN levels are first converted to NEl (in megacalories per pound of dry matter) at one times maintenance, using equations from Van Soest, Fadel, and Sniffen. The Van Soest discounts are then applied to account for the decline in energy obtained from a unit of feed as intake increases above the maintenance energy level. This is done separately for each representative farm, and for each group of cows high (H), medium (M), low (L), and dry (D), because of the different feeding levels assumed. From this, the nutrients per unit of feed, as fed, are calculated for inclusion in the LP models.

NEm and NEg at 1.5 times maintenance are also calculated from TDN using equations from Van Soest, et al. These are adjusted to an average energy (in megacalories per pound of dry matter) for the two groups of heifers, 3 to 12 months (H1), and 12 to 30 months

(H2). This calculation is based on the proportion of total energy requirements for maintenance and gain. Finally, the energy levels are adjusted to levels per unit of feed as fed.

Table 12. PERCENTAGES OF LEGUME AND GRASS ASSUMED FOR FORAGES
Limited Resource Farms, New York, 1986

	Number of cuts	Percent grass	Percent legume
<u>Soil group 3</u>			
Alfalfa-timothy, year 1	1.0	20	80
Alfalfa-timothy, years 2,3	2.5	20	80
Alfalfa-timothy, years 3,4	2.0	30	70
<u>Soil group 6</u>			
Trefoil-alfalfa-timothy, year 1	1.0	35	65
Trefoil-alfalfa-timothy, years 1,2,3	2.0	35	65
Trefoil-alfalfa-timothy, years 4,5,6	1.0	70	30
Grass hay	1.0	100	0

Construction of the Linear Programming Model

The organization of the linear programming models used to analyze the representative farms is outlined in Figure 1. The objective of each model is to maximize returns for a given level of resources. Since the study examines short-term strategies, the objective functions maximize returns over variable costs. Relationships among the broad categories of activities are indicated by the X's in the cells of the matrix. Individual coefficients for each activity in the linear programming model come from the budgets and data sets discussed in the preceding sections.

Activities in the Model

Individual activities allow for the sale of milk, cull cows, cull heifers, bull calves, heifer calves and two grades each of alfalfa-timothy and trefoil-alfalfa-timothy hay. Cows are divided into four production groups (high, medium, low, and dry) and heifers into two groups (H1 and H2) based on age. In models where levels of production higher than the base level are allowed, additional vectors are added which represent higher production levels by the high, medium, and low groups of cows. Six vectors are used to sum dry matter consumption for the livestock groups. An additional vector allows for the transfer of one-fourth of the maintenance energy from the high group to the low group of cows to simulate weight loss during peak production.

Each cow and heifer production group has separate activities for each type of feed. For example, cows in the high group have activities for consumption of corn grain, soybean meal, corn silage, alfalfa hay-crop silage(1), alfalfa hay-crop silage(2), alfalfa hay(1), alfalfa hay(2), trefoil hay(1), trefoil hay(2), and grass hay. Ten activities allow for the storage of the various feeds. These activities are in hundredweights for corn and soybean meal, and tons for the hays and forages.

FIGURE 1. SCHEMATIC OF LINEAR PROGRAMMING ANALYSIS FOR REPRESENTATIVE FARMS

Objective function and constraints	Categories of Activities					
	Sales of milk, stock and hay	Livestock production groups	Ration balancing groups	Feed storage	Forage production	Purchases of feed and labor
Objective function MAX return over variable costs	X	X			X	X
Resource accounting, land, labor, cows, and silo capacity		X			X	X
Crop harvest and feed purchases				X	X	
Feed transfer	X		X	X		
Ration balancing for cows and heifers		X	X			
Product transfers to sale	X	X				

There are two corn silage production activities, one for each soil group. Three activities each are included for alfalfa-timothy, and trefoil-alfalfa-timothy production. These are for the establishment year, the early years, and the later years of production. Two activities allow production of grass hay on rented land, and grazing. Each of the forage production activities is based on one acre of production.

Further activities allow for the purchase of corn grain, soybean meal, alfalfa hay, and trefoil hay. Labor hiring activities allow for obtaining extra day labor during the cropping season.

Constraint Equations in the Model

Four equations limit the amounts of soil group three, soil group six, rented grass hay, and grazing land available. Two further equations implement the corn silage rotational constraints by limiting its production to 50 percent of soil group three, and 30 percent of soil group six. Other equations ensure that the proportions of establishment year, early years, and later years, of alfalfa-timothy, and trefoil-alfalfa-timothy are correctly maintained.

One equation limits the number of early lactation cows to the number specified by the model. A further three ensure that the other three cow-production groups have the same number of cows. Heifer numbers are maintained as a fixed proportion of cow numbers.

A series of equations limits labor use on a monthly basis. Labor used by the activities in any month is constrained by the limit for the particular model plus hired labor at $5 per hour.

Crop harvesting and purchase of concentrates is achieved by equations which transfer corn grain, soybean meal, alfalfa-timothy hay and silage, trefoil-alfalfa-timothy hay, and grass hay from the production and purchase activities to storage activities. The coefficients in the cropping activities reflect yields of product after harvesting losses have been deducted.

A further series of constraints moves the feeds from storage to the ration balancing activities. Storage losses are deducted on removal of the feed from storage, and feeding losses are deducted on its transfer to the ration balancing activities.

Thirty-two equations are used to control the nutritional requirements of the four groups of cows (H, M, L and D) and the two heifer groups (H1 and H2). Each of these groups has three equations which: limit dry matter intake; ensure a minimum amount of energy in the diet; and ensure that minimum crude protein requirements are met. Each of the cow groups has two equations which count the dry matter intake, and use this to ensure a minimum level of adjusted acid detergent fiber is achieved. The dry cow and heifer groups each have equations which limit the proportion of their dry matter which can be obtained from pasture. Figure 2 summarizes the method used to balance the livestock nutritional requirements.

FIGURE 2.

RATION BALANCING EQUATION FOR LINEAR PROGRAMMING MODEL
Average Resource Farms, New York, 1986

	Milk Activities									Replacement Heifers		Feeding Activities Alfalfa Silage 1					
	High production				Low production			Dry cows									
Constraints	140cwt	150cwt	DMsum	TranNE	140cwt	150cwt	DMsum	Dry	DMsum	H1	H2	High	Low	Dry	H1	H2	RHS
Objective function	-262	-266								-79							
DM Max (H)	-4144	-4270										800					< = 0
DM Acct. (H)			-1									800					= 0
Min NE (H)	-3129	-3299		1								502					> = 0
NE transfer	-241	-241		1													< = 0
Min CP (H)	-655	-693										127					> = 0
Min ADF (H)			-0.15									251					> = 0
DM Max (L)					-3326	-3393							800				< = 0
DM Acct. (L)							-1						800				= 0
Min NE (L)				-1.05	-2152	-2239							521				> = 0
Min CP (L)					-405	-425							127				> = 0
Min ADF (L)							-0.15						251				> = 0
DM Max (D)								-1383						800			< = 0
DM Acct. (D)									-1					800			= 0
Min NE (D)								-711						537			> = 0
Min CP (D)								-115						127			> = 0
Min ADF (D)									-0.15					251			> = 0
Max Past. (D)								-691		-822					800		< = 0
Min NE (H1)										-581					441		> = 0
Min CP (H1)										-142					127		> = 0
Max Past. (H1)										-411							< = 0
DM Max (H2)											-3617					800	< = 0
Min NE (H2)											-1815					469	> = 0
Min CP (H2)											-390					127	> = 0
Max Past. (H2)											-1808						< = 0

Finally, five equations are used to transfer milk, cull cows, cull heifers, bull calves, and heifer calves from the production activities to the sales activities.

Evaluation of Management Strategies

Evaluation of Basic Representative Farms

The two categories of representative farms established for this study are the small tractor-bucket (SB) and large tractor-pipeline (LP) farms. In the initial stages of this study, three cropping systems of the SB farm, and two cropping systems of the LP farm are evaluated as well. The differences among the cropping systems result from the forage crops harvested and their associated equipment complements and storage requirements.

The results of the FMES survey indicate that 41 percent of the SB farms harvest no corn silage, and 61 percent harvest no hay-crop silage. In order to capture some of this variation, the three types of SB farms analyzed are:

1. SBCSH -- This farm has the equipment and storage facilities to utilize corn silage, hay-crop silage, and hay.

2. SBCH -- This farm has the equipment and storage facilities to utilize corn silage and hay, but not hay-crop silage.

3. SBAllH -- This farm did not have any silage equipment or storage and could only produce hay.

The FMES survey indicated that 83 percent of the LP farms harvested corn silage, but that 33 percent did not produce hay-crop silage. Two types of farm are modelled in this case. They are:

1. LPCSH -- This farm has the equipment and storage facilities to utilize corn silage, hay-crop silage, and hay.

2. LPCH -- This farm has the equipment and storage facilities to utilize corn silage and hay, but not hay-crop silage.

In all other respects, the farms had the same levels of resources and coefficients as outlined earlier.

Assets and Fixed Costs of the Farms

The asset values assumed for each of these farms are given in Table 13. Valuations of farmland, buildings, and improvements for the CSH farms are taken from the averages for SB and LP farms in the FMES survey, while values for the CH and AllH farms are adjusted from the CSH values. This method underestimates the valuation for the CSH farms, because it assumes that all SB and LP farms in the FMES survey have silos and silage equipment. The assumption is more appropriate for the LP farms than the SB farms, as most of the former harvest silage, while a smaller proportion of the latter do so.

Table 13. ASSET VALUATION OF SMALL-TRACTOR-BUCKET AND LARGE-TRACTOR-PIPELINE FARMS
Limited Resource Farms, New York, 1986

	SB Farms			LP Farms	
	CSH	CH	AllH	CSH	CH
Farmland, buildings and improvements	$105,000	$105,000	$ 96,000	$184,000	$182,000
Machinery and equipment	73,000	71,000	44,000	110,000	99,000
Livestock	29,000	29,000	29,000	76,000	76,000
Total	$207,000	$205,000	$168,000	$370,000	$358,000

Source: FMES Survey Data.

Estimates are made of construction costs of concrete tower silos for storage of corn silage, and horizontal silos for storage of hay-crop silage, based on the quantities of these silages produced on the farms. The SBCSH farm is assumed to require a 225 ton tower silo and a 75 ton horizontal silo, while the LPCSH farm is assumed to require a 550 ton tower silo and a 150 ton horizontal silo. A capacity of 75 tons is small for a horizontal silo; an alternative is to use a plastic bag for storage.

The calculated machinery valuations are much higher than the corresponding average valuations for machinery for SB and LP farms from the FMES survey. Machinery valuations from the DFBS data for farms of similar size are also lower, although the differences are not quite so large. Part of this difference could be due to undervaluation of machinery in the surveys. This might happen because farmers' valuations might have been based on inventories for tax purposes, which are generally lower than the replacement cost of the machinery. It is also possible that not all machinery is included. Since the proportional difference between the survey values of machinery and this study's estimated values is much larger for the SB farms than the LP farms, one likely explanation is that older equipment is being used on these farms than is assumed and hence has a lower market value. Some sharing of equipment with neighbors or family members may occur as well.

Table 14. FIXED COSTS FOR SMALL TRACTOR-BUCKET AND LARGE TRACTOR-PIPELINE FARMS
Limited Resource Farms, New York, 1986

	SB Farms			LP Farms	
	CSH	CH	AllH	CSH	CH
Labor					
Hired	$3,182	$3,182	$3,182	$14,578	$14,578
Unpaid family	2,738	2,738	2,738	1,776	1,776
Land building & fence repair	1,272	1,272	1,272	1,683	1,683
Taxes	2,701	2,701	2,701	4,065	4,065
Real estate rent & lease	567	567	567	1,504	1,504
Telephone	453	453	453	611	611
Insurance	1,709	1,675	1,128	2,871	2,685
Building depreciation	2,570	2,495	1,121	6,469	6,319
Machinery depreciation	10,862	10,546	6,008	16,108	15,664
Interest on total assets	10,345	10,230	8,408	18,494	17,876
Total	$36,400	$35,859	$27,578	$68,159	$66,761

Sources: Based on costs on similar farms in DFBS, 1986.

Since the linear programming models optimize return over variable cost, fixed costs must be subtracted to obtain adjusted labor and management income per operator (Table 14). These fixed costs include: hired and unpaid family labor, land, building and fence repair, taxes on real estate, rental of land, telephone, insurance, building depreciation, machinery depreciation, and interest on total assets. Labor costs, land, building and fence repair, telephone, taxes, insurance, and building depreciation are estimated from data obtained from the DFBS. Land rental is derived from average cash rental rates per acre from the FMES data adjusted for quantity of land rented. Machinery depreciation is estimated using the equipment complements for each farm. As already indicated in the discussion of assets, these values may be overestimates, especially for the SB farms. In 1986, the average machinery depreciation expenses obtained in the DFBS survey were: $4,567 for farms with less than 40 cows (average 34), and $13,388 for farms with 70 to 84 cows (average 76). Interest is calculated on total asset value at a real rate of interest of five percent (Smith, et. al., 1986).

Relative Profitability of Representative Farms

The initial optimal solutions using linear programming for the representative farms are derived using milk sales of 10,750 pounds per cow and 14,000 pounds per cow for the SB and LP farms, respectively. All farms showed positive returns over variable costs (Table 15). The return over variable costs for the LP farms is approximately three times the return for the SB farms, although the LP farms have twice the number of cows; for example, the level for the LPCSH farms is $67,456 vs. $23,794 for the SBCSH farm. The returns for the CH and AllH farms are only slightly lower than the returns for the CSH farms.

Table 15. PROFITABILITY OF REPRESENTATIVE FARMS

	SB Farms			LP Farms	
	CSH	CH	AllH	CSH	CH
Return over var. costs	$23,794	23,576	21,997	$67,456	67,098
Fixed costs	36,400	35,859	27,578	68,159	66,761
ALMI*	-$12,606	-12,283	-5,581	-$703	337
ALMIO**	-$12,606	-12,283	-5,581	-$562	270

* Adjusted labor and management income.

** Adjusted labor and management income per operator using 1 operator for SB farms and 1.25 operators for LP farms.

After adjustment for estimated fixed costs, the LP farms show almost no labor and management income while the SB farms show large negative amounts ranging from -$5,581 for the AllH farm to -$12,606 for the CSH farm (Table 15). If a return to capital of five percent had not been included as part of fixed costs, the losses on the SB farms would have been $-2,261 (CSH) and $-2,053 (CH). The all hay farm would have had a positive return of $2,827. For the LP farms, the net returns to labor, management and capital would be $17,791 (CSH) and $18,213 (CH) respectively.

A comparison of these results can be made with the 1986 DFBS summary figures for similar sizes of farms. To make the comparison, their reported results of labor and management income per operator are adjusted for a standard five percent interest cost on debt capital. The average ALMIO for DFBS farms with less than 40 cows is $105 while for farms with 70 to 84 cows, the figure is $3,048. These results might be compared with the SB and LP representative farm results, respectively. The LP results are not strikingly different, whereas the SB results are significantly lower. However, while the average level of milk sales per cow for the DFBS data is only slightly higher, 15,705 vs. 14,000 for the LP comparison, it is much higher, 14,695 vs. 10,750 for the SB comparison, so the SB results would be expected to be lower. The SB farms as constructed have much higher machinery inventory values and hence depreciation costs are higher than for the DFBS farms, which would also tend to reduce their labor and management incomes still further.

A smaller loss is indicated for the SBAllH farm (all hay) in comparison to the other two SB farms. However, since the study is not designed to analyze the optimal hay-making strategy, the comparison should be interpreted with caution. The CSH farms are limited in the quantities of hay-crop silage they can produce. Secondly, the linear programming models used are not able to measure the gains in productivity which could be made from improved quality of hay-crop silage. Thirdly, much of the difference is due to the assumptions made about fixed costs. Since the difference between the farms in return over variable costs is only approximately $1,600, the decreased losses of the all hay farm is largely a result of lower equipment costs (and to a lesser extent lower building and improvement valuations).

Management Indices for Representative Farms

A review of the cropping plans and expected output is useful in assessing the performance of linear programming models. Table 16 contains the optimal land use, crop production indices, and levels of purchased feed for the optimal plans for each of the representative farms. All available tillable land is used on each of the representative farms.

One anomaly is the production of the majority of corn silage on the poorer soil (group six). This would not be expected in practice although it may be profit maximizing. It may be due to a number of factors. Farmers are generally observed to use soil group three to produce corn silage because of the risk associated with growing corn silage on poorer land. The better drainage improves the probability of being able to harvest all the crop in bad seasons. The models are not designed to take this factor into account. A larger differential in yields between the two soil types is needed to force the corn silage to be grown on the better quality land. The models also assume the quality of the corn silage harvested from the two soil groups is the same. In reality, there is likely to be a higher proportion of corn in the silage from soil group three, giving it a higher energy concentration.

Yields of corn silage dry matter per acre for the representative farms are similar to the averages for the DFBS and FMES farms; however, yields of hay-crop dry matter are lower. Average yields for DFBS farms for 1986 are 2.1 tons dry matter per acre for farms with less than 40 cows, and 2.6 tons dry matter for farms with 70 to 84 cows (Smith, et. al., 1987). Average yields reported for the FMES farms are slightly lower than this, with hay yields of 2.3 tons per acre for SB farms and 2.4 tons per acre for LP farms. Harvested forage dry matter averages for DFBS farms in 1986 are slightly higher than the levels for the representative farms, with farms with less than 40 cows averaging 6.9 tons per cow and farms with from 70 to 84 cows averaging 8.0 tons per cow. This is not surprising given the higher yields per acre on these farms and approximately the same acreages of forage per cow being harvested. Also, the DFBS farms have higher milk yields per cow and would be expected to use more forage. Both factors imply a higher standard of management on the DFBS farms than for the farms established for further analysis here.

One possible explanation of the lower levels of forage used on the representative farms is that the linear programming models because of ration balancing hay and forage are used more efficiently than on actual farms. A number of assumed factors could contribute, including: lower levels of losses, higher quality of feed, and the required ration balancing for the representative farms models. The representative farms would be expected to have better ration balancing than typical practicing farms, because the model implicitly minimizes the cost of the rations within the nutritional constraints. It also assumes that the productivity level and nutritional content of the feeds are accurately known, which is not generally the case in reality. The linear programming nutritional constraints are also a simplification of reality because they do not include all the nutritional factors, and assume the rations are correctly balanced at all times.

Purchased feed costs per cow for the SB farms are approximately half the levels for the LP farms. Both are lower than the averages for the DFBS farms in 1986. DFBS farms with less than 40 cows spent $521 per cow, while farms with 70 to 84 cows spent $466 per cow. A major contributing factor to this is the lower levels of production on the representative farms, especially the SB farms.

Table 16. OPTIMAL PLANS FOR FIVE LIMITED RESOURCE FARMS
New York, 1986

	SB Farms			LP Farms	
	CSH	CH	AllH	CSH	CH
<u>Land use</u> (acres)					
Corn silage (3)*	6	6	0	13	13
Alfalfa-timothy (3)	27	27	33	52	52
Idle (3)	0	0	0	0	0
Corn silage (6)	20	20	0	32	32
Trefoil-timothy (6)	46	46	66	76	76
Grass hay (6)	32	32	32	47	47
Idle (6)	0	0	0	0	0
Total tillable	130	130	130	220	220
Pasture (8)	53	53	53	80	80
Idle (8)	2	2	2	0	0
<u>Indices</u>					
Tillable ac/cow	3.5	3.5	3.5	3.0	3.0
Corn silage t DM/ac	2.9	2.9	--	4.0	4.0
Hay crop t DM/ac	1.4	1.4	1.4	1.4	1.4
Stored forage t DM/cow	6.0	5.9	4.9	6.1	5.9
<u>Purchased feed</u>					
Corn grain (cwt)	712	768	1,543	2458	2566
Soybean meal (cwt)	180	178	48	809	807
Alfalfa hay (t)	1	0	1	20	17
Purchased feed cost/cow	$169	$174	$255	$337	$342

* Numbers in parentheses indicate the soil group.

Despite these limitations, the linear programming models provide a reasonable simulation of the situation of a number of "limited resource" farms indicated by the DFBS and FMES data, since the management indices are in reasonable agreement. Possible weaknesses of the models include: inflated equipment complements, especially for the SB models, and an inability to completely simulate the effects of improved forage quality on productivity per cow.

Effect of Increased Productivity

Procedure for Increasing Production Per Cow

In the initial models, the levels of milk sales for the representative farms are 10,750 pounds per cow for SB farms and 14,000 pounds per cow for LP farms. To analyze the effects of increased production on the farms, this initial restriction is released in two ways. The first is to determine the maximum level of production which could be achieved on both the SBCSH and LPCSH farms. The second is to see the effect of increases in milk sales of 1,000 and 2,000 pounds per cow on each farm.

The procedure for allowing increased milk sales involves introducing activities for cow production at higher sales levels, and allowing the program to optimize accordingly. The only changes in these activities are increases in nutritional requirements, increased milk output, and increased variable costs of production. This implicitly assumes that nutrition is the only constraint to increased production and that the main method used to achieve this increase is to improve the nutritional quality and quantity of the feed. It also assumes that no other changes are required, such as increased labor for milking, increased fixed costs, or improved management of other components of the business. Cow numbers are, of course, held constant.

Maximum Possible Levels of Production

When the production constraints are released, the maximum levels of milk sales which could be achieved are 16,500 pounds per cow for the SBCSH farm and 18,000 pounds per cow for the LPCSH farm. Although the linear programming algorithm allows an increase of this size, it is unlikely that this type of change could be achieved without other factors changing at the same time. It does indicate an upper bound of production which could be achieved on these farms given the quality of farm produced forage and the nutritional assumptions of the models. In other words, if these farms are to achieve higher levels of production than the maximums calculated, they would need to improve the quality of the feed produced, and/or be able to buy other high quality feeds not allowed by the assumptions in this study.

Effect of Increased Production on SB and LP farms

The second, more realistic alternative for examining the effect of increased production, is to allow increases in milk sales of 1,000 and 2,000 pounds per cow in the short run. Such changes are more likely to be achievable within current management and resources on these farms. Each increase of 1,000 pounds of milk per cow increases labor and management income for the

SB farms by approximately $2,500 and for the LP farms by about $4,000 (Table 17). The results are positive ALMIO's for the LP farms, and substantial decreases in the losses for the SB farms. Approximately the same increases occurred for the CH and AllH farms as occurred for the CSH farms. The effect of the first 1,000 pound increase is slightly greater than the effect of the second increase, indicating decreasing returns to such increases in production.

Table 17. EFFECT OF INCREASING MILK SALES ON ADJUSTED LABOR AND MANAGEMENT INCOME PER OPERATOR
Limited Resource Farms, New York, 1986

	Cropping System of Farms		
Increase in milk sales	Corn silage, hay-crop silage and hay	Corn silage and hay	Only hay
Small tractor-bucket milking farms (SB):			
Initial AIMIO at 10,750 lbs. milk sales per cow	-$12,606	-$12,283	-$5,581
		- Increases in AIMIO -	
Increase of 1,000 lbs/cow to 11,750	+ 2,465	+ 2,465	+ 2,510
Increase of 2,000 lbs/cow to 12,750	+ 4,857	+ 4,865	+ 4,942
Large tractor-pipeline farms (LP):			
Initial AIMIO at 14,000 lbs. milk sales per cow	-$ 562	$ 270	
		- Increases in AIMIO -	
Increase of 1,000 lbs/cow to 15,000	+ 4,133	+ 4,120	
Increase of 2,000 lbs/cow to 16,000	+ 8,042	+ 8,030	

The higher levels of production require increased purchases of corn grain and soybean meal, and reductions in the quantity of home-produced hay and hay-crop silage used (Table 18). Only the results for the CSH farms are presented as similar changes occurred on the other farms. Purchased feed cost on the SB farm increases from $169 per cow to $220 per cow for the first 1,000 pound increase, and $274 per cow for the 2,000 pound increase.

The corresponding increases for the LP farm are from $337 per cow, to $380 per cow, to $427 per cow. Production of corn silage shifts marginally from soil group six to soil group three, with increases in production on the SB farm, while production of alfalfa-timothy, and trefoil-alfalfa-timothy declines. Some soil group six land is idle because sales of hay are not included as an activity in the program. A similar pattern occurs with the LP models, although it is not as pronounced, partly because the initial effect is to decrease purchases of alfalfa hay, which are not significant for the SB models.

Table 18. EFFECT OF INCREASED MILK SALES ON PRODUCTIVE ACTIVITIES OF LIMITED RESOURCE FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
Land use (acres)						
Corn silage (3)	6	6	7	13	13	13
Alfalfa-timothy (3)	27	26	25	52	52	52
Idle (3)	0	0	0	0	0	0
Corn silage (6)	20	19	17	32	32	32
Trefoil-timothy (6)	46	44	40	76	76	75
Grass hay	32	32	32	47	47	47
Idle (6)	0	4	9	0	0	1
Total tillable	130	130	130	220	220	220
Indices						
Tillable ac/cow	3.5	3.4	3.3	3.0	3.0	3.0
Corn silage t DM/ac	2.9	3.0	3.0	4.0	4.0	4.0
Hay crop t DM/ac	1.4	1.4	1.4	1.4	1.4	1.4
Stored forage t DM/cow	6.0	5.8	5.7	6.1	5.8	5.8
Purchase feed						
Corn grain (cwt)	712	895	1081	2458	2876	3093
Soybean meal (cwt)	180	262	342	809	1012	1205
Alfalfa hay (t)	1	0	0	20	0	0
Purchased feed cost/cow	$169	$220	$274	$337	$380	$427

An important implication of the linear programming results is the relationship between feed quality and level of milk production. The increases in milk sales are achieved through decreasing the use of poorer quality forages and replacing them with sources of higher energy and protein grains. If increases in milk production had been raised further, larger areas of land would have been left idle by the linear programming procedure. The poorer quality land is not producing the quality of feed required to allow the cows to produce at higher levels. Feed produced on the idle land has a lower marginal value product than its cost of production, hence, it is not included. The cropping system would need to be improved if more of the feed supply was to come from the farm itself.

An alternative use for the idle land would be to sell hay. In these models, the objective function coefficients for hay sales are set at zero, and hence, hay sales did not occur. However, Table 19 provides the minimum price at which sales of the different qualities of hay would have occurred at the various levels of milk production. These are the internally calculated marginal value products of hay now produced and are a function of the quality of that hay and its use in increased levels of milk production. Better quality hay has a higher value because of its higher energy and protein content. If selling hay had been included at prices above these values, profitability would have been further increased.

Table 19. IMPLICIT MINIMUM SALE PRICE FOR HAY ON FARMS HARVESTING CORN SILAGE, HAY, AND HAY-CROP SILAGE
Limited Resource Farms, New York, 1986

Class of hay	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
Alfalfa-timothy(1)	$78	$72	$72	$78	$78	$69
Alfalfa-timothy(2)	56	48	48	56	56	44
Trefoil-timothy(1)	54	45	45	54	53	41
Trefoil-timothy(2)	40	31	31	45	45	40

The shadow prices of all qualities of hay decline as milk production levels increase. Two related factors cause this. First, at higher production levels the required content of energy and protein in the feed is higher and more concentrates are purchased in total and as a proportion of the diet. The value of home-produced hay becomes less because of its low energy and protein content relative to milk production requirements. Second, the internal marginal value of extra land declines, (for poor quality land to zero, when some is idle) because less hay is required, and hence the internal "cost" of producing hay is lower. An implication is that at higher levels of production it would be more profitable to sell low quality hay (at a given market price for hay) since its internal value to cows is lower. This is accentuated in the case of hay from soil group six, as some of this land is no longer used to produce forage for cows.

Table 20. SENSITIVITY OF OPTIMAL SOLUTIONS TO CHANGES IN CONCENTRATE PRICES
Limited Resource Farms, New York, 1986

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
Corn price/cwt.	$ 5.70	$ 5.70	$ 5.70	$ 5.70	$ 5.70	$ 5.70
Upper bound	9.72	9.72	9.72	6.21	6.19	11.15
Lower bound	5.11	4.10	4.10	5.01	4.99	5.69
Soybean price/cwt.	$11.60	$11.60	$11.60	$11.60	$11.60	$11.60
Upper bound	14.63	14.63	14.63	14.77	14.70	11.70
Lower bound	9.94	7.85	7.85	9.53	9.45	8.40

The optimal activity levels are not sensitive to changes in the price of milk, with a decrease of about $4.50 per cwt required before the solution changes. The optimal solutions for the SBCSH farms are not particularly sensitive to changes in concentrate prices (Table 20), but the solutions for the LPCSH farms are more sensitive, particularly for corn prices.

Increased Yields of Hay and Hay-crop Silage

Procedure for Increasing Yields

Increasing yields of forage has two beneficial effects on profitability. It can decrease the per unit cost of forage, and increase the amount of high quality forage available. Although soil quality has an important influence on potential yields of forage, adoption of improved management techniques can also lead to improved production without significantly increasing cost. Such improvements might include: use of varieties best suited to the soils, improved establishment techniques (especially weed control), timeliness of operations, and improved harvesting and grazing management.

The average yields of hay and hay-crop silage are slightly lower for the representative farms than the averages indicated by the DFBS and FMES data. The effect of increased hay and hay-crop silage yields on the optimal results for the representative farms is tested by increasing pre-harvest yields of alfalfa-timothy and trefoil-alfalfa-timothy by 20 percent for the CSH farms. Yields of hay and hay-crop silage are calculated in the same manner as discussed earlier. All other costs and coefficients remained the same, since it is assumed the improvements are in management techniques similar to those mentioned above, and required minimal resource changes or expenditures. The interaction of improved yields with increased milk production is further assessed by allowing increases in milk sales of 1,000 and 2,000 pounds per cow.

Effect on Labor and Management Income

Net income (ALMIO) increased by slightly more than $1,000 for the SB farms, and by less than $2,000 for the LP farms when yields were increased but quality held constant (Table 21). This is a modest effect on profitability given the relatively large

Table 21. EFFECT OF INCREASE IN FORAGE YIELDS ON ADJUSTED LABOR AND MANAGEMENT INCOME PER OPERATOR FOR LIMITED RESOURCE FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY

Impact of hay yield change	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
			ALMIO			
Before increase	$-12,606	$-10,141	$-7,749	$ -562	$3,571	$7,480
After increase	-11,474	-9,074	-6,739	1,382	5,270	9,050
			- Net increase in ALMIO -			
Change from increased yields of hay	+ 1,132	+ 1,067	+1,010	+1,944	+1,699	+1,570
Change from both hay and milk		+ 3,532	+5,867		+5,832	+9,612

increase in hay and hay-crop silage yields, however, no other simultaneous changes are allowed. For example, hay sales are not considered, despite an increase in idle acreage of soil group six (Table 22). The internal marginal value products of hay are also lower, e.g., the value of trefoil-timothy(2) hay for the SBCSH farm producing at 10,750 pounds per cow, decreased from $40 per ton, to $22 per ton. These factors imply hay could be produced and sold, and result in a larger increase in net income than is possible without hay sales.

As milk sales per cow increase, the magnitude of the increase in ALMIO declines for both farms (Table 21). At higher production levels, low quality forage is less able to meet the cows' increased demand for energy and protein, and a decline in the magnitude of the increase in ALMIO from higher yields of forage would be expected. Increasing amounts of high protein and high energy concentrates are required at these higher production levels. Support for this is reflected in a small decline, with increased milk production levels, in the difference between purchased feed costs per cow, of farms with and without, the increased forage yields. It is important to remember that in all cases, the projected increase in net income from increased hay yield, is in addition to the gain from increased milk sales.

Table 22. LEVELS OF PRODUCTIVE ACTIVITIES FOR FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY WHEN HAY AND HAY-CROP SILAGE YIELDS ARE INCREASED

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
Land use (acres)						
Corn silage(3)	8	9	10	15	17	18
Alfalfa-timothy(3)	24	23	22	50	49	47
Idle(3)	0	0	0	0	0	0
Corn silage(6)	16	15	14	31	28	25
Trefoil-timothy(6)	37	35	32	71	65	59
Grass hay	32	32	32	47	47	47
Idle (6)	13	17	21	7	15	24
Total tillable	130	130	130	220	220	220
Indices						
Tillable ac/cow	3.2	3.1	3.0	2.9	2.8	2.7
Corn silage tDM/ac	3.1	3.1	3.1	4.0	4.1	4.2
Hay crop t DM/ac	1.6	1.6	1.6	1.7	1.7	1.7
Stored forage tDM/cow	6.0	5.9	5.7	6.3	6.1	5.9
Purchase feed						
Corn grain (cwt)	705	886	1072	2289	2674	3071
Soybean meal (cwt)	175	255	335	857	1024	1192
Alfalfa hay (t)	0	0	0	0	0	0
Purchased feed $/cow	$164	$216	$270	$311	$367	$424

Effect on Productive Activities

With the increase in forage yields, larger amounts of land are left idle due to a decline in trefoil-timothy production on soil group six, and there is a consequent decline in the tillable acres per cow index (Table 22). Another change is a slight shift of corn silage production from soil group six to soil group three. The latter effect results in an increase in the average corn silage yield per acre. Both corn grain and soybean purchases decline slightly with the increase in forage yields, due to the increased yields of hay and hay-crop silage from soil group three, with their higher energy and protein contents.

Increased Quality of Hay and Hay-crop Silage

Procedure for Increasing Quality

The quality of a forage depends on the levels of energy and protein it contains. Higher quality forages can form a larger proportion of a cow's ration and decrease the requirement for purchased concentrates. Low quality forages can limit production if they can't profitably be replaced with higher quality feeds. Forage quality is a function of factors such as the plant composition of the forage, the time of harvest, harvesting methods, harvest losses, and storage conditions. Johnson examined the effects of management on profitability of dairy farms by altering the amount of time allowed to conduct harvesting operations. Improved management resulted in early harvest of the forage, higher quality, and hence increased profitability.

Procedures for estimating the total digestible nutrients, crude protein, and acid detergent fiber percentages for the hay and hay-crop silages were outlined earlier. These estimates are based on assumed average harvest dates for the different classes of forage. To estimate the impact of increasing forage quality, the same procedures are followed, but the average harvest dates for each of the forages are moved forward one week. The main effect of this is to improve the quality of the first cut, which increases the average quality of all the classes of hay and hay-crop silage. A comparison of the total digestible nutrients (TDN), crude protein, and adjusted acid detergent fiber (ADF) levels for the two assumed cutting dates are given in Table 23. The differences which resulted from this assumption are important even though small, with increases in TDN being less than three percent, crude protein levels less than one percent, and decreases in adjusted ADF less than two percent. Besides these gains in nutrient quality, palatability commonly increases as well.

Table 23. COMPARISON OF NUTRIENT CONTENT OF FORAGES WITH ONE WEEK ADVANCE IN TIME OF HARVEST
Limited Resource Farms, New York, 1986

Forage	% TDN		Crude protein % DM		Adjusted ADF % DM	
	One week earlier	Regular	One week earlier	Regular	One week earlier	Regular
Alfalfa-timothy silage (1)	63	61	16.7	15.9	29.7	31.4
Alfalfa-timothy hay (1)	60	58	18.3	17.3	32.4	33.9
Alfalfa-timothy silage (2)	57	55	14.2	13.9	35.1	36.6
Alfalfa-timothy hay (2)	53	50	14.7	14.0	38.7	40.5
Trefoil-timothy hay (1)	53	50	14.3	13.6	38.7	40.5
Trefoil-timothy hay (2)	49	48	10.9	10.3	44.2	45.6
Grass hay	49	48	8.3	7.9	44.2	45.6

Effect on Net Income

Despite the relatively modest change in nutrient content of the feeds, ALMIO increases approximately $800 for the SB farms and $1,100 for the LP farms (Table 24). The relative magnitude of these increases declines as production per cow increases. The combination of increased production and increased value of the higher quality feed establishes an important gain in total.

Table 24. EFFECT OF INCREASE IN FORAGE QUALITY ON ADJUSTED LABOR AND MANAGEMENT INCOME PER OPERATOR FOR LIMITED RESOURCE FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY
New York, 1986

Change in forage quality from one week advance in harvest	Level of milk sales -- lbs. per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
	- Labor and Management Income -					
Before increase	$-12,606	$-10,141	$-7,749	$- 562	$ 3,571	$ 7,480
After increase	-11,786	- 9,336	-6,985	635	4,652	8,538
	- Change in Labor and Management Income -					
Change from harvest date	+ 820	+ 805	+ 764	+1,197	+1,081	+1,058
Combined change from date of harvest and increased milk		+ 3,270	+5,621		+5,214	+9,100

An important reason for the increases in net income is a reduction in purchased feed costs (Table 25). These became smaller in each scenario, as a result of decreases in corn grain and soybean meal purchases. Alfalfa hay purchases increase because the alfalfa hay purchased is assumed to be the same quality as alfalfa-timothy (1) hay (Table 23), and the price of the hay is kept constant. This assumes the farmer is able to buy slightly better quality hay than before, without paying extra (a weakness in the model formulation which disappears with a 2,000 pound increase in milk production).

Table 25. LEVELS OF PRODUCTIVE ACTIVITIES FOR AVERAGE RESOURCE FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY WITH INCREASED FORAGE QUALITY New York, 1986

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
	10,750	11,750	12,750	14,000	15,000	16,000
Land use (acres)						
Corn silage(3)	6	6	7	13	13	14
Alfalfa-timothy(3)	27	27	26	52	52	51
Idle(3)	0	0	0	0	0	0
Corn silage(6)	20	20	19	32	32	32
Trefoil-timothy(6)	46	46	43	76	76	74
Grass hay	32	32	32	47	47	47
Idle(6)	0	0	4	0	0	2
Total tillable	130	130	130	220	220	220
Indices						
Tillable ac/cow	3.5	3.5	3.4	3.0	3.0	3.0
Corn silage tDM/ac	2.9	2.9	3.0	4.0	4.0	4.0
Hay crop tDM/ac	1.4	1.4	1.4	1.4	1.4	1.4
Stored forage tDM/cow	6.3	6.0	5.8	6.3	6.0	5.8
Purchase feed						
Corn grain (cwt)	601	804	997	2237	2674	3092
Soybean meal (cwt)	98	203	290	664	884	1099
Alfalfa hay (t)	11	1	0	38	17	0
Purchased feed $/cow	$147	$190	$245	$317	$362	$410

Effect on Productive Activities

The optimal areas of crops for the models with increased forage quality (Table 25) are only marginally different from the optimal cropping plans for the models with the original forage quality (Table 18). It might be expected that there would be less idle land because land producing forage would replace purchased concentrates, but this pattern occurs only for the SB farms. Purchased feed costs per cow and quantities of purchased concentrates are lower for the models with increased forage quality in all cases. The LPCSH farms with increased and original forage qualities had approximately the same levels of idle soil group six land when milk sales are 16,000 pounds per cow. This could mean that at higher levels of production, the assumed increase in forage quality on the soil group six land is not sufficient to make increased use of this land.

The emphasis has been placed here on the effect of producing higher quality forage on profitability. An alternative view might be to consider the reverse, and consider the effect on this model of decreasing forage quality. The forage quality assumed for this study may be higher than actually exists on many farms of this type in New York State. This could be one explanation for the relatively low purchased feed expenditures per cow implied by this model for the SB farms. If the assumed quality of forage had been lower, the quantities and cost of purchased feed would necessarily have been higher. An equally important result of the model is that the rations are balanced automatically assuming full knowledge of forage quality; this is unlikely in reality. Many farmers probably have limited knowledge about the nutritional content of their forages and are not able to formulate rations accurately. The result is poorer than expected production levels obtained from the concentrates purchased.

Relax Restriction on Storage of Corn Silage

In the initial models, storage of corn silage is restricted to 225 tons for the SB farms, and 550 tons for the LP farms. The storage restriction is instituted for two reasons: (1) Without the restriction, the models will produce about 50 percent more acres of corn silage than the average for the FMES representative farms, and (2) silage storage is often a restriction on dairy farms (Milligan, 1988). The restriction is relaxed to: (1) estimate the effect of the restriction on profitability assuming sufficient storage is available, and (2) estimate the likely return from building extra storage if this storage space is limiting. To investigate these alternatives, the storage restriction is removed for SBCSH farms selling 10,750 and 12,750 pounds of milk per cow, and for LPCSH farms selling 14,000 and 16,000 pounds of milk per cow.

Effect of Storage Restriction on ALMIO for CSH Farms

Relaxing the restriction without increasing storage costs produced little effect on profitability of the SB farms, increasing net income by approximately $500 (Table 26). The effect is more important for the LP farms resulting in an increase in net income of about $2,000. This might have been expected since the dual values for a unit of extra storage for the LP farms are approximately twice the values for the SB farms. A couple of factors are probably responsible for the difference: higher yields of corn silage on the LP farms, lower tillable acres per cow for the LP farms, and higher production levels, which increase the benefits from the high energy corn silage.

Table 26. EFFECT OF RELAXING RESTRICTION OF CORN SILAGE STORAGE ON ADJUSTED LABOR AND MANAGEMENT INCOME PER OPERATOR FOR FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY

Remove corn silage storage restriction	Level of milk sales - lbs per cow			
	SB farm		LP farm	
	10,750	12,750	14,000	16,000
	- Labor and Management Income -			
With restriction	$-12,606	$-7,749	$ -562	$ 7,480
Without restriction	-12,082	-7,269	1,720	9,232
Change	+ 524	+ 480	+2,282	+1,750

Comparison of Increased Income with Fixed Costs of Extra Storage

A comparison is made of the increased returns from relaxing the corn silage restriction, with the annual costs of building extra storage for the SBCSH farm producing 10,750 pounds per cow, and the LPCSH farm producing 14,000 pounds per cow. The extra storage space required is 115 tons and 294 tons, respectively, for the SB and LP farms. Implicit in this is that storage released from lower production of alfalfa-timothy silage can not be used for corn silage. This is reasonable since the two types of silage need to be kept separate to some degree.

Two types of storage are considered: concrete tower silos and horizontal concrete silos. The small amount of extra silage involved makes the former impractical for the SB farm. The extra annual return over variable costs for relaxing the corn silage restriction on the SB farm is $524. This compares with extra annual storage costs of $316 for 115 tons of storage capacity. Although this results in a positive return, the difference is minimal. Other factors, such as the risk involved with having such a large area of silage, which has to be harvested in September and October, may be important. For the case of the SB farms, the storage restriction is probably not distorting the results.

Relaxing the storage restriction for the LP farms increases the return over variable costs by $2,847 per year. The estimated annual costs for a concrete tower silo are $3,138, while the costs for a horizontal silo are $650. A tower silo would not, therefore, be justified but the horizontal silo could be. Since the average farm is not growing this acreage of corn silage, it suggests other factors (e.g., availability of suitable quality land close enough to main barn), which are not included in the models in this study, might be constraining such production.

Relax Rotation Restriction on Final Years of Alfalfa-timothy and Trefoil-timothy Production

Explanation of Restriction

The initial models assume that alfalfa-timothy on soil group three is grown for five years, and trefoil-timothy on soil group six is grown for seven years. Each of the crops is split into three production periods. For alfalfa-timothy, the establishment year: years two to three and years four to five. For trefoil-timothy, the establishment year: years two to four and years five to seven. The restriction requirements for the last periods are relaxed so that they can be included only if they are profitable. With shorter rotations, yields are higher and quality is improved due to earlier and more frequent cutting. The benefits are offset by increased establishment costs and reduced yields in the first year. The hypothesis is that shorter rotations will increase net income. This is tested by running the models for SBCSH farms selling 10,750 and 12,750 pounds of milk per cow and for LPCSH farms selling 14,000 and 16,000 pounds of milk per cow.

Changes from Relaxing the Rotation Restriction

Relaxing the rotation restriction makes little difference to net income for both the SB and LP farms with the increases being less than $100 in all cases (Table 27).

In the case of the SB models, the length of rotation is not reduced for alfalfa-timothy but is reduced for trefoil-timothy. The model with the low production per cow included 9.6 acres of years five to seven of trefoil-timothy, while 1.4 acres of years five to seven of trefoil-timothy are included in the model with the higher production per cow.

Table 27. EFFECT OF RELEASING ROTATION RESTRICTION FOR ALFALFA-TIMOTHY AND TREFOIL-TIMOTHY ON ADJUSTED LABOR AND MANAGEMENT INCOME PER OPERATOR FOR FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY

Effect of shorter rotation if profitable	Level of milk sales - lbs per cow			
	SB farm		LP farm	
	10,750	12,750	14,000	16,000
	- Labor and Management Income -			
With restriction	$-12,606	$-7,749	$ -562	$ 7,480
Without restriction	-12,579	-7,699	-503	7,557
Net change	+ 27	+ 50	+ 59	+ 77

For the LP models, the opposite occurs with the length of rotation being reduced for alfalfa-timothy, while no change occurs for trefoil-timothy. Years four to five of alfalfa-timothy are not included at either of the production levels.

Purchased feed costs per cow are reduced for both the SB and LP models by these rotation changes, but are offset by higher variable production costs for the forage produced as a result of the shortened rotation. The implication of these results is that shortening the rotation for hay and hay-crop silage, based on the assumptions in this model, does not lead to significant increases in profitability.

Other Factors Influencing Profitability

Number of Cows

This study does not consider the effect on profitability of increasing herd size. The marginal benefits to be gained from expansion can be compared for the differing situations considered using the duals for the cow number restriction. These give the increase in return over variable cost for a unit increase in cow numbers. These duals are listed in Table 28 for the original CSH farms and for the effects of increased milk sales, forage production, and forage quality. An increase of 2,000 pounds of milk sold per cow for the SB farm raises the dual values from $460 to $638, while a similar increase for the LP farm raises the dual values from $604 to $835. The right hand side ranges for cow numbers are sensitive to changes in size which means the duals would have to be recalculated for relatively small changes in herd size.

The results suggest that these farms can improve their profitability significantly without resorting to the large capital investments inherent in increasing herd size. Increasing production per cow is likely to increase the gains in profitability from increasing herd size if the higher level of production is maintained after the change. Increased forage production and forage quality will also increase profitability in combination with higher production per cow. The message from this for limited-resource farms is that important gains in profitability can be made by improving management of existing resources without large capital outlays. These gains will then improve the expected profitability of herd expansion once improved forage production has been combined with larger milk sales per cow.

Table 28. CALCULATED INCREASES IN RETURN OVER VARIABLE COST FOR A UNIT INCREASE IN COW NUMBERS Limited Resource Farms, New York, 1986

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
Scenario	10,750	11,750	12,750	14,000	15,000	16,000
	Increase in return over variable cost per cow					
Base farm situation	$460	$573	$638	$604	$674	$835
Increased forage production	552	617	680	758	824	887
Increased forage quality	509	576	668	653	722	867

Effect of Milk Price

In general, the optimal solutions to the models in the study are not sensitive to changes in milk price. For CSH models, the optimal solution does not change until the milk price net of marketing costs declines to $7.12 per hundredweight for SB farms and $7.39 per hundredweight for LP farms. This compares with prices of $11.40 and $11.70 per hundredweight, respectively, used in the models. Increasing profitability through improved production per cow and improved forage quantity and quality leads to a further decline in the lower bound of milk price.

Summary of Results

Apart from their interaction with increased production per cow, each of the management strategies considered was analyzed independently. Table 29 summarizes for the CSH farms the increase in net income which occurs when each of the strategies is implemented. It also shows the effect when the strategies are combined with increased production. For example, on the SB farm when production is increased by 1,000 pounds to 11,750, the net increase in ALMIO is $2,465. When the gain from improved forage quality of $820 is added, the total effect for 11,750 cows is $3,270 (Table 29).

Of the management strategies considered in the study, improving production per cow appears to be the individual strategy which will lead to the most significant improvement in profitability without requiring large capital investments.

Table 29. INCREASE IN ADJUSTED LABOR AND MANAGEMENT INCOME ABOVE INITIAL LEVELS FOR LIMITED RESOURCE FARMS HARVESTING CORN SILAGE, HAY-CROP SILAGE, AND HAY

	Level of milk sales - lbs per cow					
	SB farm			LP farm		
Scenario	10,750	11,750	12,750	14,000	15,000	16,000
Initial net income		-$12,606			-$562	
Effect of:	Increase in net income above initial level					
Production increase	--	$2,465	$4,857	--	$4,133	$8,042
Improve forage quantity	1,132	3,532	5,867	1,944	5,832	9,612
Improve forage quality	820	3,270	5,621	1,197	5,214	9,100
Increase corn silage	524	--	5,337	2,282	--	9,794
Shorter hay-crop rotation	27	--	4,907	59	--	8,119

Increasing forage quantity and quality both result in worthwhile improvements in profitability and lead to even greater improvements when combined with increased production. Increasing the quantity of corn silage appears also to be beneficial for the LP farms with the net effect depending on the cost of extra storage space.

If a number of these strategies were combined, the effect on profitability would be expected to be even greater than the individual effects. Since none of them require major changes or large capital investment, they should be within the capacity of operators of these types of farms if and when they change the required management practices and are able to implement them accordingly.

General Conclusions

1. An important first strategy for improving profitability on limited-resource dairy farms in New York State is to improve milk production per cow.

2. Farms with low profitability and low productivity per cow can significantly improve their profitability using a combination of the strategies outlined in this study which do not require significant capital investment or expansion in herd size.

3. Improvements in quality of hay-crop forage on limited-resource farms are likely to result in greater increases in profitability than increases in quantity of forage. If farms are already feeding high levels of concentrates, then significant improvements in profitability through increased production per cow entails improvements in the quality of the forage. Improvement in quantity of forage produced will only be beneficial if it is high quality forage which can be used to replace low quality forage in the diet.

4. If limited-resource farms are feeding low proportions of concentrates to forage and the forage is of mediocre quality, then these farms could improve profitability by increasing production per cow through balancing the ration. This may require increasing the proportion of concentrates in the diet. This may lead to "surplus" lower quality forage which could be sold to further increase returns.

5. An expansion in herd size should be considered only after improvements have been made in the quantity and quality of forage produced and increases in milk production per cow have been realized and maintained.

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