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AN ANALYSIS OF THE EFFECTS OF FIELD OPERATIONS MANAGEMENT ON NEW YORK DAIRY FARMS

by

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Crop production is an important component of Northeast and Lake State dairy farm businesses. Most dairy farms in these areas own and/or rent cropland to produce feed for their dairy enterprises and/or to produce cash crops to sell on the open market. Dairy farms in the New York Dairy Farm Business Summary (Smith and Putnam, 1983, 1984) average over three acres of tillable cropland per cow. This average is fairly constant through all sizes (number of cows) of dairy farms. The primary use of this cropland is forage production for feed. Forage production on the 1983 Dairy Farm Business Summary farms average over 75 percent of total tillable acreage. Hay and corn crops produced on the farms account for a substantial portion of the dairy herd's feed requirement.

This interaction between dairy and crop enterprises has a large impact on farm profitability. In addition, the crop enterprises should be viewed as individual profit centers with the management goal of optimizing returns to the resources committed to those enterprises. The profitability of the crop enterprises on the dairy farm is determined by the efficient use of available time, labor, and machinery field capacity to schedule and perform field operations in a manner that optimizes crop yields and quality. Untimely planting or harvesting of crops reduces crop yields and quality leading to reduced income through decreases in milk production, increased purchased feed expenses, or a decrease in potential crop sales.

This study examines the economic effects of crop management practices on dairy farm businesses. The primary objective is to

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analyze the impact on profitability of optimally managing field operations in terms of the time, labor, and capital resources which have been committed to the crop enterprises.

Farm profitability in this research is measured as return to the operator's labor and management, unpaid family labor, and the fixed resources of land, buildings, and machinery. This reflects the short term profitability of the farm. Most of crop management practices discussed are those that farm managers can apply in the short run, that is, a year or less, to improve crop programs.

Methodology

Representative New York dairy farms are modeled and analyzed to meet the objectives of this study. Herd sizes, acreage bases, soil types, and labor resources are the distinguishing characteristics of the representative farms. The capital resources of dairy facilities and machinery compliments are established. Nutrition needs are specified. Cropping alternatives and field operation requirements are determined. Time availability for field operations is determined. Prices, input levels, and production levels are specified. The relationship between all of these activities and factors are outlined. The analytical tool of enterprise budgeting is employed in this process to determine the enterprise receipts, variable expenses, and fixed expenses for various enterprise combinations.

The representative farms are modeled and analyzed using the mathematical optimizing algorithm of linear programming (LP). The objective is to maximize returns over selected variable expenses. The initial LP optimal solution represents farms that are fairly efficient in scheduling and performing field operations. These farms have normal resources with field operations constrained only by time available for field work and machinery capacity.

Under these conditions, the LP solution specifies the optimal schedule for field operations. The shadow prices for the different time periods will indicate those time periods, and consequently the field operations that are most critical in increasing profitability.

Inefficient crop management is represented by decreasing time availability and forcing field operations into suboptimal time periods. By observing how large these decreases must be before field operations are modified and profitability is reduced, conclusions can be drawn about the importance of management.

Decreased profitability through deviation from the optimal schedule will show up through increased purchased feed expenses, changes in crop sales, and decreased milk production.

Improved crop management techniques are represented by including simultaneous field operations and purchasing larger or more efficient equipment. The results can be seen in the profitability increases. Comparing this increase to machinery ownership and operating costs can determine if these are viable alternatives.

Representative Farms and Linear Programming Model

In this study, farms with two different resource levels are modeled to analyze the effects of field operation management on small and large farms commonly found in New York State. The general characteristics of the two resource levels for the representative farms are defined in terms of herd size, livestock facilities, land resources, crop enterprise alternatives, necessary field operations, machinery resources, management resources, labor resources, and general constraints. The two resource levels are utilized to develop 16 representative farms. These 16 farms are designated as the large and small farms. In as much as possible, the characteristics of two sizes of dairy farms (40 to 80 cow, 80 to 150 cow herds) have been incorporated into the representative farms. These farms are also distinguished as farms where the crop program focus is on forage production to meet the roughage requirements of the dairy herd. Hay sale activities are included on the representative farms. Corn grain can be sold on the large farms. Sales are expected to be minimal, representing a small excess over the dairy enterprise's feed requirements. The characteristics of the two resource levels are summarized in Table 1.

The dairy herds on both farm sizes are fed in two production feed groups and a dry group. While cows are usually fed individually in a stanchion barn, they were grouped this way to simplify modeling of the feed program. The high production feed groups cover the first 17 weeks of lactation and the low production feed groups cover the last 27 weeks of lactation (Milligan, 1985). The herds are grouped this way to focus on meeting the nutrient requirements during the peak lactation time interval. Three production levels are specified at 13,000, 16,000, and 18,000 pounds of milk per cow per lactation period. The actual optimum production levels are selected in the LP model.

Soil resources on the large farms include 160 acres of group 2 soil and 110 acres of group 4 soil.[1] Soil resources on the small

[1]The soil groups referred to are the eight soil productivity groups used for use value assessment in New York. These groups are characterized by the land's potential yield.

farms include 65 acres of group 3 soil and 100 acres of group 5 soil (Reid, 1985). Hay and corn crops are the dominant enterprises because of nutritional, rotational, and land resource constraints. Mixed, mainly legume hay crops are produced consisting of varying ratios of alfalfa and timothy depending on soil group. Hay is seeded down with oats. The oats are harvested for grain with no cutting of hay taken off the first year. The hay rotation includes the establishment year and a minimum of three production years. There are three cuttings of hay taken off per year in the production years if hay is harvested before June 19. If harvested after that date, there are only two cuttings.

The objective of this model is to maximize returns to fixed resources. The benefits of timeliness of field operations are reflected in the yields and quality of crops produced and can be physically measured as the levels of nutrients produced. On dairy farms the benefits of timeliness in field operations are reflected in increased returns in the dairy enterprise.

The model contains approximately 350 activities and 150 constraints. The general categories of activities and constraints as well as the relationships between them are represented in a schematic of the model matrix in Figure 1. The X's in the matrix cells represent relationships between the activities and constraints. The density of this matrix is approximately 5.5 percent.

Since the focus of this study is to observe the impact of timeliness of field operations on a farm's profitability, it is important to establish the time framework by modeling the annual crop cycle in terms of increments that are short enough to reflect most of the individual scheduling problems that can have a major impact on crop yields. This framework is then the basis for most of the activities and constraints in the model. The model represents an annual planning horizon for the representative farms; however, a specific focus on the crop season from primary tillage through harvest is important in meeting the objectives of this study. The crop season is divided into 13 periods during planting and harvest.

The crop enterprise activities require that field operations be performed in the proper sequence. Groups of field operation activities corresponding to the first eight time periods are established in the model. From these groups of activities, the required field operations must be selected and sequenced for any crop enterprise activity that comes into the solution of the model.

An important part of this model is a series of constraints that represent the relationships between requirements and availability of time, labor, and management. Meeting the objectives of this study is mainly accomplished through manipulation of these constraints to observe the effects on crop and dairy enterprise activities.

A set of constraints is defined for each of the first 10 periods to represent time, labor, and management requirements and availability. The last three periods are not considered since harvesting corn grain is the only field operation and this is custom harvested which minimizes the management and labor requirements for the representative farms.

Since the increase in profitability from timeliness of operations is realized primarily through the dairy enterprise, it is important that the dairy enterprise activities are modeled so that the effects of various crop schedules can be seen on milk production and purchased feed costs. For this reason, dairy cow activities are introduced into the model for three production levels: 13,000, 16,000, and 18,000 pounds of milk per lactation period. The model determines the actual level of production. The herds are fed in high and low production groups as well as a dry cow group so the dairy cow activities are further distinguished by these characteristics. A dairy replacement heifer activity is also included. The unit of activity, then, is a dairy cow or replacement heifer with each activity being distinguished by the above characteristics. For example, an activity is defined for a dairy cow in a high feed group producing 16,000 pounds of milk per lactation period. One other livestock activity includes sales of bred heifers (Figure 2).

Receipts, expenses, and technical coefficients used to quantify the activities, constraints, and technical coefficients in the model are determined using 1983 data. In cases where the 1983 information is not available, data are extrapolated from other years using indexing or subjective judgment. The values required for the LP model are divided into four main areas: enterprise receipts and expenses, time coefficients, crop yields and nutrient values, and livestock nutritional requirements.

The model of the representative farms was run for each of the resource levels to produce the optimal allocation of resources for the large and the small farms. Constraints were then placed in the model to simulate other farm situations. These constraints created a total of 16 representative farms representing two resource levels or farm sizes, two maximum milk production levels, and four crop management scenarios. These initial representative farms are identified by their distinguishing characteristics which are found in Table 2.

The initial optimal solutions of the model set the milk production level for both herd sizes at 18,000 pounds per cow. This was expected since the initial farms were to represent efficient farm management practices. One of the objectives of the study is to determine the effect of crop management practices on milk production levels. It was hypothesized that the lower yields and quality of forages associated with poor crop management practices might force milk production levels down because the purchased corn grain and soybean oil meal could not balance with the lower quality forages to produce a ration that would meet the protein and energy requirements while meeting the fiber requirements and dry matter limits. This, however, proved not to be the case. Given the nutritional constraints in the model, all the feed requirements can be met even with suboptimal crop management practices, although formulation of a balanced ration becomes increasingly difficult as forage quality deteriorates. In actual practice this increased difficulty could be reflected in lower milk production.

Analysis of Timeliness in Performing Field Operations

The initial representative farms reflect farm managers who efficiently schedule and perform field operations. In contrast with these initial farms, inefficient field operation management scenarios are developed by altering the sequencing and time constraints in the model (Table 3).

Field operation scenarios DF01 and DF02 represent the delayed field operations of farm managers who are unprepared for field work.

Plowing and planting are delayed past the time soil conditions first permit these operations. Hay crop harvest is delayed beyond the growth stage of optimal yields and protein percentages.

In contrast to scenarios DF01 and DF02, scenarios DTL1 and DTL2 represent farmers who start field work on time, but have daily time losses. Scenario DTL1 represents a daily time loss of one hour during tillage, planting, and corn harvesting operations and a half hour loss per day during hay harvesting operations. Scenario DTL2 represents a daily time loss of two hours during tillage, planting, and corn harvesting and one hour in hay harvesting. The small farms are not as sensitive to daily time losses because the machinery complement is larger relative to the acreage to be worked; consequently, scenario DTL1 is not reported for the small farms and scenario DTL2 is adjusted to represent a three hour daily time loss during tillage, planting, and corn harvesting and a two hour daily time loss during hay harvesting. The final scenario, COM, is a combination of scenario DF01 and DTL1. These farm managers delay field operations and, once started, they do not make full use of the daily time available.

The timeliness of field operations ultimately affects the profitability of the farm business. Most of the scenarios analyzed have a significant effect on the profitability of the initial representative farms (Table 4). The loss in profitability ranges from just over $1,600 to over $21,000 for the large farms with more than half of the scenarios in excess of $10,000. For the small farms, the decreases are less; however, several exceed $5,000.

Large high-corn farms have the greatest decreases in profitability ranging from $6,043 to $21,664 as field operations are delayed. Large high-hay farms also have significant decreases in profitability ranging from $1,644 to $12,433. There were smaller decreases in profitability on the small farms ranging from $934 to $6,031. These small losses are inherent in the fact that the smaller farms have less to lose from inefficiency than the large farms. In addition, the smaller farms have a proportionately larger equipment complement to compensate for inefficient management.

There are larger losses on the large farms than there are on the small farms. Farms that have high acreages of corn have larger losses than farms that have low acreages of corn. There are also larger losses with delayed field operations than there are with daily time losses.

Decreases in profitability can be related directly to field operation timing through shadow prices generated by the model. The shadow prices for the field operations are associated with constraints that delay field operations in scenarios DF01, DF02, and COM. These shadow prices are interpreted as the increase in profitability from plowing, planting, or harvesting one acre during the time period in which the operation is not performed because of inefficient management. To illustrate, in scenario DF01 these shadow prices are $38, $23, and $109 for plowing, corn planting, and hay harvesting for the time periods in which the farm manager does not perform the operation.

Other shadow prices are associated with daily time losses. In scenarios DTL1 and DTL2 the hours of daily time available are constrained to represent farm managers who do not use all of the time each day that is available. Shadow prices associated with these constraints are interpreted as the value of obtaining another hour of time during these time periods. This is illustrated by the hourly shadow prices for Farm L18HCSHC:

Time Period	DTL1	DTL2
April 1 - 20	374	391
April 21 - May 10	374	386
May 11 - 20	348	360
May 21 - 31	330	341
June 1 - 7	126	135
June 8 - 14	131	173

These shadow prices are very large and have several implications. While they are strictly defined as the value of another hour of time during these periods, this can mean several things. These values can be associated with an hour on a good day that a farmer uses to get inputs such as seed which could have been purchased on days when the weather did not permit field work. They can represent the value of an additional hour of hired labor if labor is constraining the farm manager from working a full day in the field. They can represent the price that could be paid for an hour of custom machine hire.

The above shadow prices are typical of those on the other farms. Again, the shadow prices tend to be lower on the small farms. However, the high values on all of the farms indicate that farm managers have much to gain by using all of the time available to them.

TABLE 1

Summary of Representative Farm Resources[a]

Resource	Small Farms	Large Farms
Livestock Resources	60 cows 1350 lbs. avg. weight 50 repl. heifers (birth to freshening) Cow feed groups high prod-1st 17 wks low prod-last 27 wks dry group-8 wks Culling rate-28%	120 cows 1350 lbs. avg. weight 100 repl. heifers (birth to freshening) Cow feed groups high prod-1st 17 wks low prod-last 27 wks dry group-8 wks Culling rate-28%
Livestock Facilities	Stanchion barn Pipeline milking system Tie stalls Gutter cleaners Manure hauled daily Heifer barn	Freestall barn Herringbone parlor Manure scraped & hauled daily Heifer barn
Feed Storage Facilities	Silos, cement stave Open pole barn for hay storage	Silos, cement stave Open pole barn for hay storage
Machinery Complement	80, 60, 40 hp tractors 4-row implements	100, 80, 40 hp tractors 4-row implements
Land Resources	165 tillable acres 65 soil group 3 100 soil group 5	270 tillable acres 160 soil group 2 110 soil group 4
Possible Crop Enterprises	Hay crop silage Dry hay Corn silage Oats	Hay crop silage Dry hay Corn silage Corn grain Oats
Management	15.5 months/year operator labor & management Seasonal hired labor 4 months/year family labor	17 months/year operator labor & management Seasonal hired labor 2 months/year family labor 1 full-time employee

[a]Resources are determined from available publications and discussions with experts.

TABLE 2

Characteristics of Initial Representative Farms

Farms	Herd Size	Milk Prod. Level (lbs/cow/yr)	Hay Harvest Method	Relative Level Corn Planted
L18HCSHC	120	18,000	Hay Crop Silage	High
L18HCSLC	120	18,000	Hay Crop Silage	Low
L18DHHC	120	18,000	Dry Hay	High
L18DHLC	120	18,000	Dry Hay	Low
L16HCSHC	120	16,000	Hay Crop Silage	High
L16HCSLC	120	16,000	Hay Crop Silage	Low
L16DHHC	120	16,000	Dry Hay	High
L16DHLC	120	16,000	Dry Hay	Low
S18HCSHC	60	18,000	Hay Crop Silage	High
S18HCSLC	60	18,000	Hay Crop Silage	Low
S18DHHC	60	18,000	Dry Hay	High
S18DHLC	60	18,000	Dry Hay	Low
S16HCSHC	60	16,000	Hay Crop Silage	High
S16HCSLC	60	16,000	Hay Crop Silage	Low
S16DHHC	60	16,000	Dry Hay	High
S16DHLC	60	16,000	Dry Hay	Low

TABLE 3

Inefficient Field Operation Management Scenarios

Scenario	Farms Applied To	Characteristics
Delayed Field Operation		
DF01	All	Delay tillage until April 21 Delay corn planting until May 11 Delay hay crop harvest until June 1
DF02	All	Delay tillage until April 21 Delay corn planting until May 21 Delay hay crop harvest until June 8
Daily Time Loss		
DTL1	Large	Tilalge, planting, and corn silage harvest decreased one hour per day Hay crop harvesting decreased 1/2 hour per day
DTL2	Large	Tillage, planting, and corn silage harvest decreased two hours per day Hay crop harvesting decreased one hour per day
DTL2	Small	Tillage, planting, and corn silage harvest decreased three hours per day Hay crop harvesting decreased two hours per day
Combination		
COM	Large	Scenario DF01 and DTL1 combined
COM	Small	Scenario DF01 with additional one hour per day decrease

TABLE 4

Reduction in Returns to Operator's Labor, Management, and Fixed Capital from Inefficient Management Scenarios

Rep. Farms	Field Operation Management Scenarios				
	DF01	DF02	DTL1	DTL2	COM
L18HCSHC	$13,635	$16,787	$6,263	$13,420	$19,290
L18HCSLC	6,321	11,973	2,462	5,943	9,909
L18DHHC	14,626	17,025	6,043	13,635	20,515
L18DHLC	4,700	9,898	1,644	4,084	7,977
L16HCSHC	13,722	16,873	6,262	13,687	19,699
L16HCSLC	6,815	12,433	3,044	6,476	10,325
L16DHHC	15,271	17,764	6,525	14,932	7,407
L16DHLC	4,848	10,262	1,807	4,672	4,007
S18HCSHC	1,985	5,492		5,171	3,555
S18HCSLC	1,121	5,016		1,995	1,798
S18DHHC	2,120	5,055		4,955	3,623
S18DHLC	497	2,511		2,135	934
S16HCSHC	2,225	6,031		5,783	3,841
S16HCSLC	1,542	5,537		1,898	2,262
S16DHHC	2,252	5,346		5,629	3,757
S16DHLC	1,404	4,170		1,790	1,885

See Table 2 for characteristics of farms.

See Table 3 for characteristics of management scenarios.

Objective function and constraints	General Groups of Acitivities						
	Livestock Enterprises	Livestock Accounting	Purchased Feed	Farm Produced Feed	Crop Sales	Field Operations	Hired Labor
Returns to owner's labor, management, and fixed capital	X		X	X	X		X
Livestock Nutrient requirments	X		X	X			
Livestock constraints and accounting rows	X	X					
Time availability and labor constraints	X			X	X	X	X
Field operation sequencing constraints						X	
Acreage & rotational Contraints				X	X		

Figure 1. Schematic of LP Model

Obj. func.& constraints	Constraint type	High production feed group 13cwt	16cwt	18cwt	DMacct	Low production feed group 13cwt	16cwt	18cwt	DMacct	Dry cows	Dmacct	Repl heif	Purchased corn high	low	dry	heif	...	May 11 corn silage soil 2 high	low	dry	heif	...	RHS
Obj. function		1444	1805	2038								-48	-3.75	-3.75	-3.75	-3.75		-144	-144	-144	-144		
number of cows	E	1	1	1																			120
Max DM (lb.)	L	-4634	-5074	-5366									47.0					9481					0
DMacct high	E				-1								47.0					9481					0
Min CP (lb.)	G	-674	-799	-883									4.7					806					0
Min NE (Mcal)	G	-3517	-4118	-4530									43.0					7490					0
Min ADF (%DM)	G				-0.15								0.65					2655					0
Max DM (lb.)	L					-6565	-7079	-7423						47.0					9481				0
DMacct low	E								-1					47.0					9481				0
Min CP (lb.)	G					-843	-990	-1088						4.7					806				0
Min NE (Mcal)	G					-4540	-5212	-5670						43.0					7490				0
Min ADF (% DM)	G								-0.15					0.65					2655				0
Max DM (lb.)	L									-1482					47.0					9481			0
DM acct dry	E										-1				47.0					9481			0
Min CP (lb.)	G									-113					4.7					806			0
Min NE (Mcal)	G									-727					43.0					7490			0
Min ADF (% DM)	G										-0.15				0.65					2655			0
Max DM (lb.)	L											-5287				47.0					9481		0
Min CP (lb.)	G											-558				4.7					806		0
Min NE (Mcal)	G											-4071				43.0					7490		0
Low acct 13	E	1				-1																	0
Low acct 16	E		1				-1																0
Low acct 18	E			1				-1															0
Dry acct	E	1	1	1						-1													0
Min heiefers	G	-0.65	-0.65	-0.65								1											0

Figure 2: Illustration of Livestock and Ration Balancing Constraints

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