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COMPETITIVE POSITION OF MILK PRODUCTION IN THE NORTH CAROLINA PIEDMONT

Kevin E. Jack
and
Richard A. King

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Kevin E. Jack is a former Graduate Research Assistant and Richard A. King is M. G. Mann Professor Emeritus in the Department of Economics and Business, North Carolina State University, Raleigh, N.C.

ABSTRACT

This study analyzed the economic tradeoffs between dairying and competing enterprises under selected price and resource conditions in the Central Piedmont of North Carolina. The analysis provided insights into optimal individual producer response to changing economic conditions. Competing enterprises modelled included a beef cow herd, barley, corn, oats, soybeans, wheat, and off-farm employment.

A synthetic farm enterprise typical of Central Piedmont resource conditions was constructed using North Carolina Farm Business Management System survey data, North Carolina Agricultural Extension Service budgets, and publications of the Department of Economics and Business at North Carolina State University. Linear programming procedures then analyzed this initial on-farm resource situation to determine the optimal combination of enterprises.

The initial optimal enterprise mix was a specialized dairy operation with residual acreage devoted to wheat production. Various optimal enterprise combinations and shadow prices for selected limiting resources were calculated for alternative resource situations. Available labor was much more important than land availability in explaining overall farm profitability.

The sensitivity of the initial optimum solution was examined using price-mapping techniques. This initial mix of enterprises was very stable, with dairy production dominating the other enterprises over a wide range of milk and beef prices. Blend milk prices, net of hauling and

marketing charges, had to drop more than $3 per hundredweight from $13.68 before the size of the dairy enterprise was significantly reduced from its initial level. Beef entered the optimal farm plan only under a combination of low milk prices and high beef prices. A combination of historically low milk prices and average-to-high beef prices made off-farm employment profitable. The production of wheat, the only cash crop to be grown, was most extensive when both beef and milk price levels were low.

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This report represents a contribution to the work of regional dairy marketing research project S-217 titled Economic and Technical Forces Shaping the Southern Dairy Industry.

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I. INTRODUCTION

Dairying is an important agricultural industry in North Carolina. The sale of dairy products ranked sixth in terms of 1987 farm cash receipts following tobacco, broilers, hogs, turkeys, and forest products (North Carolina Department of Agriculture, 1988, p. 7). In 1987, North Carolina farm cash receipts from dairy product sales totalled $222.6 million and accounted for 10.7 percent of the total cash receipts from livestock and livestock products and 5.5 percent of the total cash receipts from all farm marketings.

The North Carolina dairy industry has undergone dramatic changes in recent years (Table 1). Between 1972 and 1987 the number of Grade A milk producers declined more than 52 percent, from 1,934 to 912, as many farmers found dairying to not be the best use of their resources. Despite this decline in dairy farm numbers, total milk production actually increased over this period as expansion of milk production on remaining operations more than compensated for those who left the industry.

Average daily production per Grade A milk producer increased 114 percent, from 2,177 to 4,671 pounds. This increase in average daily output was achieved by both a steady increase in average herd size from 84.3 in 1972 to 120.6 in 1987 and a 2.7 percent annual increase in average milk production per cow. Concurrently, the real annual price received per hundred pounds of milk, which is the average nominal price adjusted by USDA's Index of Prices Paid by Farmers, declined slowly, but steadily until 1985, dropping more than 25 percent from a peak of $12.17 in 1974 to $9.09 in 1987. These trends reflect changes in government programs and in alternative uses for dairy farm resources.

Table 1. Summary statistics for North Carolina dairy farming, 1972-1987[a]

Year	Number grade A milk producers (December)	Total milk production (mill. lbs.)	Average real price ($/cwt.)[b]	Average number milk cows (thous.)	Average milk production per cow (lbs.)
1972	1934	1537	12.03	163	9,429
1973	1754	1524	11.75	158	9,646
1974	1646	1534	12.17	152	10,092
1975	1586	1602	11.43	153	10,471
1976	1528	1666	10.93	154	10,818
1977	1437	1592	10.90	145	10,979
1978	1349	1557	10.56	133	11,609
1979	1301	1565	10.33	132	11,856
1980	1280	1631	10.14	134	12,172
1981	1250	1654	10.00	134	12,343
1982	1231	1686	9.25	131	12,870
1983	1222	1711	9.19	133	12,865
1984	1166	1649	9.09	130	12,685
1985	1139	1748	8.90	128	13,656
1986	1012	1695	8.81	121	14,008
1987	912	1555	9.07	110	14,136

[a]Summary statistics from various issues of North Carolina Agricultural Statistics, published by the North Carolina Department of Agriculture, Raleigh.

[b]Annual average nominal price divided by Index of Prices Paid by Farmers (1977=100) reported in Agricultural Prices, published by the United States Department of Agriculture, Washington, D.C.

This study was designed to learn more about the impact of economic conditions facing North Carolina dairy producers and to provide insights into likely producer reaction to changes in economic adjustment opportunities. In the pages that follow we:

(1) determine the optimum enterprise combinations for selected conditions on dairy farms in the Central Piedmont area;

(2) determine what changes in enterprise combinations and output would pay dairy farmers to make in response to changes in the price of milk, other selected enterprise output prices, input prices, off-farm wage rates, crop yields, and resource availability;

(3) measure the sensitivity of these optimum solutions to changes in product prices and resource availability; and,

(4) develop a general matrix of price and technical coefficients that can be adapted for other farm types and resource situations.

Linear programming was selected as the method of analysis in this study to simulate the effects of exogenous economic forces for which historical observations are not available. The representative farm model constructed here is deterministic, static, and represents a "steady state." The solution is interpreted as a stationary equilibrium solution for a representative production period. For a review of the structure of linear programming models the reader is directed to Hazell and Norton.

This research develops a representative farm and embodies this information in a linear programming matrix for analysis. Insights provided by this approach have been demonstrated in dairy studies by Dodson _et al_., Faris and McPherson, Feitshans, and Young and in beef cattle studies by Melton _et al_., Rozzi _et al_., Shumway _et al_., and Wilton _et al_. Once the linear programming model is properly formulated, the analyst is in a position to study the effects of variations in technical input-output coefficients, resource availability, and prices of inputs and outputs on the optimal combination of farm enterprises.

II. MODEL CONSTRUCTION

Selection of Study Area

The first step in this study was to identify a major dairying region of North Carolina that also contained a sufficient number of other agricultural enterprise types to allow a meaningful analysis of economic adjustment opportunities facing dairy farmers. Thus, any widespread changes in economic incentives and opportunities in this region would have considerable effects on the state's total dairy industry.

Three contiguous counties in the Central Piedmont region, Iredell, Rowan, and Davie, conformed with the needs of this study (see Figure 1). These counties ranked first, third, and ninth, respectively, in the number of milk cows and heifers that had calved as of January 1, 1987. For beef cows and heifers that had calved as of January 1, 1987, Iredell County ranked first, Rowan County ranked ninth, and Davie County ranked fourteenth (North Carolina Department of Agriculture, 1988, pp. 57-58). Consultation with Agricultural Extension Service personnel and information from North Carolina Agricultural Statistics helped determine which cash crops were grown in sufficient quantities to merit inclusion in a whole farm planning model of Central Piedmont agriculture. These cash crops included soybeans for beans, barley, wheat, oats, and corn for grain.

Data Sources

Enterprise budgets prepared by Agricultural Extension Service personnel at North Carolina State University provided detailed data on

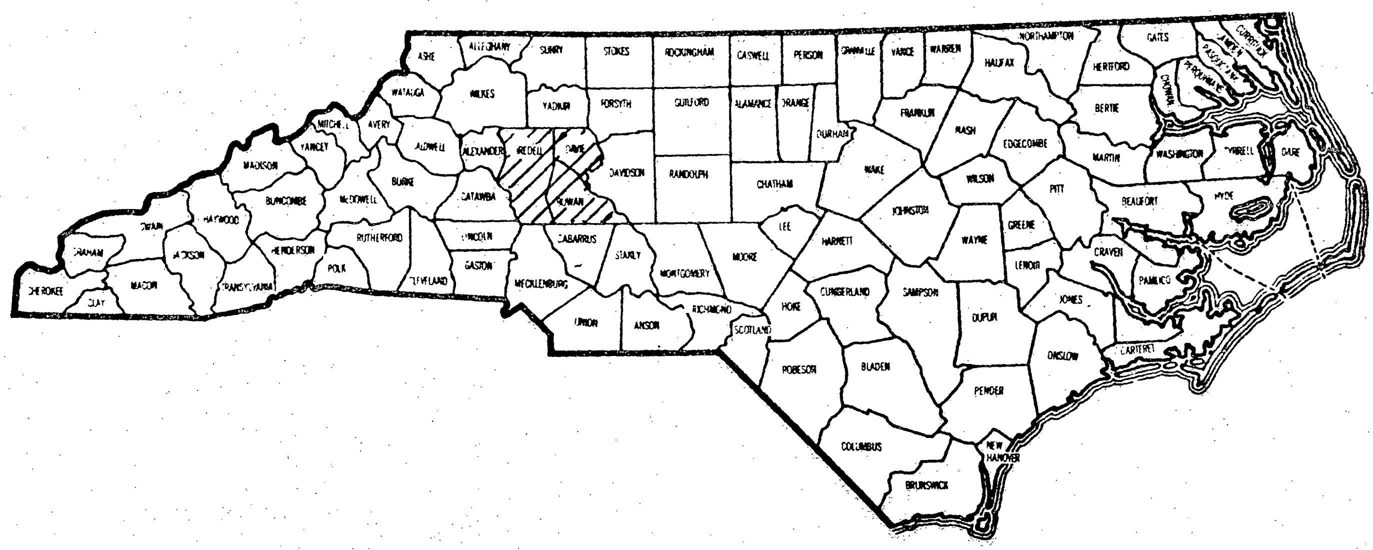

Figure 1. Area of study: Iredell, Rowan, and Davie counties,
Central Piedmont, North Carolina

technical coefficients, output prices, costs of production, crop yield estimates, machinery needs and labor requirements for the beef and dairy enterprises, cash crops, and the forage crops required for maintaining the livestock enterprises (North Carolina Agricultural Extension Service, 1983). In certain instances, cost and gross yield data were adjusted to reflect local growing conditions. Pasture and forage row crop yields were reduced for storage and livestock feeding losses. Discount percentages were obtained from published experimental data and from specialists familiar with this area.

Costs of production, technical coefficients, and nutritional requirements for the milking herd merited special attention in this study. Costs of milk production and associated technical coefficients, specifically those for labor per cow, were developed from several sources, as there was no current dairy budget appropriate for this study. These sources included older dairy budgets published by the North Carolina Agricultural Extension Service, current dairy budgets published by the Alabama Cooperative Extension Service, information from the North Carolina Farm Business Records Program, and information obtained through extensive consultation with knowledgeable personnel at North Carolina State University. Input and output prices were selected to represent levels of the mid-1980s.

Nutritional requirements for dairy cattle published by the National Research Council are embodied in the computer package used to develop a balanced least-cost ration for the milking herd and dry cows. Thus, feed requirements and costs were calculated by the computer in developing the optimal solution.

The final data requirements for this study involved detailed information on resource availability on Central Piedmont dairy farms. An exhaustive inventory of owned pastureland, owned cropland, rented pastureland, rented cropland, family labor supply, and hired labor supply was required to build a realistic model. This information was collected from the following sources: survey forms from dairy farms participating in the North Carolina Farm Business Records program; yearly issues of Dairy Farm Business Summary and Business Evaluation Workbook published by the North Carolina Agricultural Extension Service (Benson and Sutter); various issues of Cost of Producing Milk on Grade A Dairy Farms (Benson); and, Economics Information Report No. 71, North Carolina Dairy Farming, 1983 (King *et al*.).

Objective Function

The representative Central Piedmont farm developed for this study is part of a whole-farm linear programming model that allows dairy, beef, and cash crop enterprises and off-farm employment to compete for scarce agricultural inputs. The objective function in this model seeks to maximize "variable profit" for the farm. Variable profit is defined as the difference between annual revenue and variable expense. McPherson and Faris (pp. 822-823) note that variable profit (their terminology is "net return") is *not* a measure of economic profit or farm family disposable income. However, maximizing variable profit is consistent with maximizing farm family disposable income. Variable profit represents the returns to certain fixed assets, land, family labor, entrepreneurial effort, risk, and ownership costs of the bundle of depreciating capital assets outlined in Appendix Tables 1 and 2.

Overview of the Model

Model Enterprises

This model considers farm-level land-using enterprises that compete with dairying in the Central Piedmont region of North Carolina. Poultry was excluded purposely because it is not considered a land-using enterprise, but is one of several "off-farm" employment opportunities. The tables in this section present the detailed structure of the 81 rows and 62 columns of the model, and should be used in conjunction with the discussion of each major component of the tableau.

Four broad farm enterprises are found in this model: cash crops typically grown in the Central Piedmont region, a cow-calf beef herd, a dairy herd consisting of lactating or dry cows and replacements, and pasture and forage crops produced for the beef or dairy herds (Table 2). Each of these enterprises requires production, transfer, and sales activities. Transfer activities serve to move quantities from production activities to the sales activities.

All crop and livestock enterprises capable of being conducted on this farm are listed in activity columns. Each enterprise makes certain demands on the farm resource base. The technical coefficients in each column list the amount of land and labor required per acre of cropping or pasture activity, per dairy animal or per 50-cow cow-calf beef unit.

Both the beef and dairy enterprises include various animal production activities, intermediate transfer activities (defined as animal culling

Table 2. General structure of linear programming model

Row Identification and number		Labor & land	Forage crops	Cash crops	Beef herd activities	Dairy herd activities	Right-hand side
		Column identification and number					
		1-8	9-20	21-30	31-42	43-62	RHS
Objective Row[a]	C_j	A,-B,-C	-D	-D,E	-F,-G,H	-F,-G,H,I	MAX
Labor availability	1-3	Table 3					Table 3
Land availability	4-16	Table 4					Table 4
Forage yield & availability	17-40		Table 5				Table 5
Cash crop yield & sales	41-50			Table 7			Table 7
Beef herd production & sales	51-62				Table 8		Table 8
Dairy herd inventory & sales	63-78					Table 9	Table 9
Dairy herd purchased feed	79					Table 10	Table 10
Milk production & sales	80-81					Table 10	Table 10

[a] Definition of objective row values:

Letter code	Definition
A	Hourly wage for off-farm employment.
B	Hourly wage for hired labor.
C	Rent per acre.
D	Variable expense per acre.
E	Price received per acre of cash crop.
F	Variable expense per livestock unit.
G	Per head marketing charges.
H	Price received per live hundredweight.
I	Net price received per hundredweight of milk.

and weight conversion activities), and final animal sales activities. In addition, the feedstuffs supplied to each of these enterprises are explicitly accounted for by transfer rows linking the particular animal enterprise with the appropriate homegrown or purchased feed supply activity.

Selected animal types are culled from the beef and dairy herds. The movement of each type of cull animal is measured by a "weight conversion" activity, which receives animals on a per-head basis from the relevant herd. The weight conversion activity then transfers the corresponding live animal weight to an animal sales marketing activity measured in hundred-pound units.

Both the beef and dairy herds are supported by forage crop activities on the farm. These crops include various types of hays, silages, and grazed forages typically found on Central Piedmont farms. It is assumed that these forage crops are limited to on-farm use with no off-farm sales. This assumption may not be realistic for hay but is maintained to limit the scope of research.

The nutritive needs of cows in milk and dry cows are met by a combination of purchased concentrates and the produced forage crops outlined above. These nutritive needs are met on a least-cost basis discussed in greater detail later. Young stock are fed a diet based on guidelines suggested in Agricultural Extension Service heifer budgets.

<u>Model Rows</u>

Important row types in this model include: constraints on the availability of total land and row-crop land; family labor supply, hired labor supply, and off-farm work opportunities; animal feeding requirements; replacement animal control rows designed to maintain desired distributions of animal types within the beef and dairy herds; transfer rows linking animal production activities with output sales activities; accounting rows designed to measure pasture and crop production; and balance equations that transfer forage crop production to animal production activities and cash crop production to sales activities. These row types permit the analyst to measure the economic effects of changes in individual technical coefficients.

Labor Availability and Land Use-Constraints

The amounts of total land, row-crop land, and family labor are constrained at resource levels typical of those found on Central Piedmont dairy farms. North Carolina dairy farmers often hire or rent significant amounts of additional resources to complement on-farm resource levels. Land and labor supply activities are shown in Table 3 and land constraints are described in Table 4.

Farm family labor is assumed to supply a total of 5113 hours by row constraint "LABOR." Man-years of labor are converted to annual labor hours using a method suggested in Pasour (p. 33). The method of conversion is explained in Jack (p. 39). Provision is made in Column 1 for hiring up to an additional 1.0 man-year of labor to augment the on-farm family labor supply. These additional 2550 hours of labor activity, "+LABOR" in this model, may be hired at $6.50 per hour.

Table 3. Labor availability and land-use constraints

Row Number	Row ID	Labor +LABOR 1	Labor OFFFRM 2	Owned land OWNROW 3	Owned land ONRWPT 4	Owned land OWNPT 5	Rented land +ROWR 6	Rented land +ROWP 7	Rented land +PAST 8	RHS
OBJ. ROW		-6.50	5.50	0	0	0	-40	-40	-15	MAX
1	LABOR	-1	1							≤ 5113
2	MX+LAB	1								≤ 2550
3	MXOFF		1							≤ 2000
4	MXOWNL			1	1	1				≤ 190
5	MXOWNR			1						≤ 140
6	MXORP				1					≤ 140
7	MXONPT					1				≤ 50
8	MXROW			1	1					≤ 140
9	MXRENT						1	1	1	≤ 130
10	MXRTRR						1			≤ 95
11	MXRTRP							1		≤ 95
12	MX+PT								1	≤ 35
13	MXRTRA						1	1		≤ 95
14	MXRTPT							1	1	≤ 130
15	ROWEQ			-1			-1			= 0
16	PTEQ				-1	-1		-1	-1	= 0

Table 4. Land constraints in linear programming model

Name of land constraint	Row number	Description of constraint	Total acres
MXOWNL	4	Owned land	190
MXOWNR	5	Owned row-crop land (either use)	140
MXORP	6	Owned row-crop land for pasture	140
MXONPT	7	Owned pasture land (pasture only)	50
MXROW	8	All row-crop land (owned and rented)	140
MXRENT	9	All rented land	130
MXRTRR	10	Rented row-crop land for row-crops	95
MXRTRP	11	Rented row-crop land for pasture	95
MX+PT	12	Rented pasture land (pasture only)	35
MXRTRA	13	Rented row-crop land (either use)	95
MXRTPT	14	All rented land (pasture only)	130

This hiring restriction is imposed by row constraint 2 "MX+LAB". Above-average Skilled hired labor is assumed. This amount of hired labor plus family labor supply equals the number of man-years of labor found on median-size dairy farms participating in the North Carolina State University Farm Business Records Program (Benson and Sutter, 1987, p. 33).

One enterprise option in this model not typically found in farm-level programming plans is an off-farm work activity. Up to 2000 hours of the family labor supply may be devoted to off-farm employment at a wage rate of $5.50 per hour. This is realistic, given the employment opportunities available in the area. A prime example would be employment in the poultry business. This activity is "OFFFRM" in column 2 of the model and is constrained by row 3 "MXOFF."

Total on-farm land availability is assumed to be 190 acres, of which 140 are suitable for either row crops or pasture activity, with the balance capable of growing only pasture. Columns 3 to 5, "OWNROW", "OWNPT," and "ONRWPT", simply provide an accounting of how the 190 acres of owned farmland is allocated among row crop and pasture uses. Additional row-crop land may be rented at $40 per acre and used to grow either row crops or pasture. Rented row-crop land used for row crop production is denoted as activity 6 "+ROWR" in this model. Rented row-crop land utilized as pasture is activity 7 "+ROWP". Activity 8 allows pasture to be rented for $15 per acre. Of the 130 maximum total number of acres that may be rented by the farmer, 95 acres are cropland capable of supporting row crops or pasture. Rented pasture and rented row-crop land used to grow pasture crops are assumed to have the same productivity.

Model rows "ROWEQ" and "PTEQ" strike a balance between potential sources and uses of farmland. Row 15 "ROWEQ" balances the supply of row-crop land provided by the owned cropland activity "OWNROW" and the rented cropland activity "+ROWR," with the uses of row-crop land including silages, hay, and cash crops. A balance between sources and uses of pasture is struck by row 16 "PTEQ." Land suitable for grazing includes rented pastures ("+PAST"), owned pastures ("OWNPT"), and where economically feasible, rented row-crop land ("+ROWP") and owned row-crop land ("OWRWPT").

Forage Activities

All forage crops capable of being grazed or harvested on the farm are listed in the crop production columns 9 through 20 of Table 5. Crop yields, derived from enterprise budgets prepared by Agricultural Extension Service personnel at North Carolina State University, are measured in tons of hay-equivalent per acre for the grazing activities, and in tons per acre for the crops harvested for hay or silage used by the livestock enterprises. Variable costs of production per acre are placed in the objective row with negative signs, and labor requirements in hours per acre are placed in row 1. Land requirements for each silage and hay harvested activity are measured in acres as indicated by the "1" found in row 15 and for grazed forages by a "1" entered in row 16.

Rows 17 through 28 represent accounting rows, each with a "Y" prefix, designed to measure growing activity of each forage crop. Entries in these rows consist of the yields found in Table 6. Note that the yields for the silages, hays, and grazed crops shown in Table 6 do not represent the quantities available for consumption by the livestock

Table 5. Forage crop activities

ROW NUMBER	ROW ID	Grazed FESPT 9	ORGPT 10	RYEPT 11	MILPT 12	LADPT 13	Harvested COSIL 14	SOSIL 15	RHS	
OBJ. ROW		-90.76	-107.04	-92.86	-110.10	-39.73	-164.70	-131.50	MAX	
1	LABOR	.8154	.9825	1.322	2.136	.308	3.802	3.117	<=	5113
15	RQWEQ						1	1	=	0
16	PTEQ	1	1	1	1	1			=	0
17	YFESPT	3.25							>=	0
18	YORGPT		3.25						>=	0
19	YRYEPT			2.5					>=	0
20	YMILPT				3.25				>=	0
21	YLADPT					3			>=	0
22	YCOSIL						15		>=	0
23	YSOSIL							22	>=	0
24	YSGSIL								>=	0
25	YFEHY								>=	0
26	YORGHY								>=	0
27	YALFHY								>=	0
28	YALFHL								>=	0
29	XFP	-2.275							<=	0
30	XOP		-2.275						<=	0
31	XRP			-1.75					<=	0
32	XMP				-2.275				<=	0
33	XLP					-2.1			<=	0
34	XCS						-12.3		<=	0
35	XSOS							-18	<=	0
36	XSGS								<=	0
37	XFH								<=	0
38	XOH								<=	0
39	XAH								<=	0
40	XAHL								<=	0

Table 5 (continued)

ROW Number	ROW ID	Harvested SGSIL 16	FEHY 17	ORGHY 18	ALFHY 19	ALFHL 20
OBJ. ROW		-97.39	-138.54	-154.80	-170.35	-174.14
1	LABOR	3.599	6.9144	7.0815	10.5075	6.4885
15	ROWEQ	1	1	1	1	1
24	YSGSIL	7				
25	YFEHY		4			
26	YORGHY			4		
27	YALFHY				4	
28	YALFHL					10
36	XSGS	-5.74				
37	XFH		-3.44			
38	XOH			-3.44		
39	XAH				-3.44	
40	XAHL					-8.17

Table 6. Summary of storage and feeding losses for selected forage crops

Forage crop	Row number	Row ID	Yield (tons)	Storage and feeding loss (percent)	Feed available (tons)
Grazed:					
Tall fescue	9	FESPT	3.25	30	2.275
Orchardgrass	10	ORGPT	3.25	30	2.275
Winter rye	11	RYEPT	2.5	30	1.75
Millet	12	MILPT	3.25	30	2.275
Ladino-clover grass	13	LADPT	3.0	30	2.1
Harvested:					
Corn silage	14	COSIL	15.0	18	12.3
Sorghum silage	15	SOSIL	22.0	18	18.04
Small grains silage (wheat)	16	SGSIL	7.0	18	5.74
Fescue hay	17	FEHY	4.0	14	3.44
Orchardgrass hay	18	ORGHY	4.0	14	3.44
Alfalfa hay	19	ALFHY	4.0	14	3.44
Alfalfa haylage	20	ALFHL	10.0	18.3	8.17

Sources: G.A. Benson, personal communication; W.K. Waters, "Costs of Alternative Forage Harvest and Storage Systems," Pennsylvania State University, 1979; G.S. Willett, "An Economic Analysis of Alternative Forage Programs for Dairy Cattle in Western Washington." Washington State University, November 1980, p. 6.

activities. Rather, these figures denote production before storage and feeding losses of hay and silage, and before animal harvesting losses of grazed forage are deducted.

The yield rows are followed by transfer rows 29 through 40, each with an "X" prefix. The entries in these rows are yields after adjustment for animal harvesting, storage and feeding losses as found in the final column of Table 6. They carry a negative sign because these activities serve as a source of nutrients, and are used to supply forages to meet feeding requirements of either the beef or dairy herd as described later. Values in the right-hand side column (RHS) are >= for the "Y" rows and <= for the "X" rows.

Cash Crop Activities

Soybeans for beans, corn for grain, oats, barley, and wheat are the cash crop enterprises found in this model. No provision is made for these crops to be fed to livestock. Assumptions regarding labor requirements, costs of production, and yields were based on information found in various issues of North Carolina Agricultural Statistics, budgets prepared by the Agricultural Extension Service, and year-end summaries for dairy farms in Iredell, Rowan, and Davie counties provided by the North Carolina State University Farm Business Records Program.

Turning to the structure of the model (Table 7), each of the cash crop production activities (columns 21-25) has an objective row value that represents the variable operating costs associated with planting, maintaining, and harvesting one acre of the crop. Capital and overhead

Table 7. Cash crop production and sales activities

Row number	Row ID	Cash crop production GROSOY 21	GROCRN 22	GROWT 23	GROOT 24	GROBY 25	RHS
OBJ. ROW		-104.50	-134.00	-87.40	-84.10	-85.80	MAX
1	LABOR	2.474	2.994	1.509	1.689	1.569	<=5113
15	ROWEQ	1	1	1	1	1	=0
41	YSOY	25					>=0
42	YCORN		90				>=0
43	YWHET			45			>=0
44	YOATS				60		>=0
45	YBARL					65	>=0
46	XSOY	-25					<=0
47	XCORN		-90				<=0
48	XWHET			-45			<=0
49	XOATS				-60		<=0
50	XBARL					-65	<=0

Row number	Row ID	Cash crop sales $SOY 26	$CORN 27	$WHET 28	$OATS 29	$BARL 30
OBJ. ROW		5.70	1.90	2.90	1.65	1.90
46	XSOY	1				
47	XCORN		1			
48	XWHET			1		
49	XOATS				1	
50	XBARL					1

expenses are excluded from this value. This figure carries a negative sign because it reduces the variable profit of the entire farm. Labor requirements are shown in row 1 and cropland required in row 15. Rows 41-45 serve as output accounting rows. Assumed yields in bushels are as follows: soybeans 25, corn 90, wheat 45, oats 60 and barley 65.

The bushel output of one acre of each crop production activity is transferred by balance equations 46-50 with an "X" prefix to sales activities 26-30 with a "$" prefix measured in individual bushel units. For example, one acre of soybean production ("GROSOY") makes available twenty-five bushels, which are linked to bushel sales activity "$SOY" by balance equation 46 "XSOY." The various cash crop selling activities have objective function values that measure farm price received per bushel net of off-farm marketing charges. Note that sales values are not adjusted for on-farm production costs since these are included in the cash crop production activity columns.

Beef Herd Activities

Cow-Calf Beef Operation Overview

The soils and topography of Iredell, Rowan, and Davie counties are compatible with roughage systems required to support cow-calf production. Therefore, beef production may compete with dairying and cash cropping in the Central Piedmont region.

The beef enterprise in this model has several components that are discussed in subsequent sections of this study. At the core of this enterprise is a 50-cow herd that represents the production aspects of the enterprise. Beef output flows from this production component of the enterprise to a per-head culling component. This component consists of "weight conversion" activities that receive beef output from the herd measured on a per-head basis. The output of these weight conversion activities is in turn transferred to the beef marketing activities, which are measured in units of one-hundred pounds.

Beef Herd Production

Beef production budgets prepared by Agricultural Extension Service specialists at North Carolina State University indicate that on an annualized basis, a 50-cow herd employing a 14% culling rate in its breeding herd and experiencing a 90% calf crop yield and 2% death loss, on average, will yield 22.5 male calves and 22.5 female calves. All of the male calves are marketed as 525 pound steers. Of the 22.5 heifer calves, 10.5 are sold at a weight of 475 pounds and 12 are retained to replace brood cows that were culled or died. On average, one-third of the 12 retained heifer calves fail to conceive and are culled at 750 pounds. The remaining 8 heifer calves enter the breeding herd as brood cows.

The linear programming model rows in Table 8 represent labor requirements (1), pasture and silage requirements (29-34), animal flows (51-58) and marketing rows (59-62). Replacement animal control row 57 "NMREPL" moves the twelve potential replacement animals from the beef herd activity "COWCF" to heifer-growing activity "HFGRO". In turn, the one-third of the potential replacement heifers that do not conceive are moved from "HFGRO" to animal marketing activity "MHFCUL" by replacement animal control row 54 "BHHFCL." The remaining two-thirds are moved from

Table 8. Production and sales activities, 50 cow-calf beef herd

Row number	Row ID	COWCF 31	Replacements BCDIE 32	HFGRO 33	HFREP 34	RHS
OBJ. ROW		-2127	0	0	0	MAX
1	LABOR	450				<=5113
29	XFP	32.5				<= 0
32	XMP	32.5				<= 0
33	XLP	150				<= 0
34	XCS	140				<= 0
51	BHDEAD	-1	1			>= 0
52	BHREPL	8			-1	<= 0
53	BHHGRO			-.667	1	= 0
54	BHHFCL			-.333		= 0
55	NMBSTR	-22.5				<= 0
56	NMBHF	-10.5				<= 0
57	NMREPL	-12		1		<= 0
58	NMCLCO	-7				<= 0
59	BWTSTR					<= 0
60	BWTHF					<= 0
61	BWTCHF					<= 0
62	BWTCCO					<= 0

Row number	Row ID	Animals marketed M525ST 35	M474HF 36	MHFCUL 37	MCOW 38	Hundredweight sold B#STR 39	B#HEIF 40	B#HFCL 41	B#COW 42
OBJ. ROW		-11.34	-8.37	-12.38	-12.6	72	62	55	42
54	BHHFCL			1					
55	NMBSTR	1							
56	NMBHF		1						
57	NMREPL								
58	NMCLCO				1				
59	BWTSTR	-5.25				1			
60	BWTHF		-4.75				1		
61	BWTCHF			-7.5				1	
62	BWTCCO				-10				1

"HFGRO" activity to brood cow replacement activity "HFREP" by animal control row 53 "BHHGRO." The eight replacement heifers required are transferred from the heifer replacement activity to the main breeding herd by replacement animal control row 52 "BHREPL." Finally, a death rate of 2%, or one cow per 50, is modelled with row 51 "BHDEAD" moving dead animals to disposal activity "BCDIE."

The objective row value of -2127 in cow-calf herd activity column 31 measures all direct variable costs, excluding labor and forage costs, attributable to a herd of 50 cow-calf units. All labor required for the herd is entered in row 1 of column "COWCF." Management practices reflect those outlined in Agricultural Extension Service Budget #20-2 (Appendix Table 3).

Beef Herd Nutrition

As outlined earlier, successful cow-calf beef operations in the Central Piedmont region depend on grazing for the major nutrient source. Pastures must provide most of the nutrients necessary for heifers and steers to achieve optimal weight gains and for brood cows to support nursing calves. Other forage crops often supplement grazing so that proper nutrient requirements and balances are met.

North Carolina Agricultural Extension Service Budget #20-2 reports the nutritional needs of one cow-calf unit in per-acre amounts of mixed ladino clover and grass pasture, coastal bermuda grass pasture, fescue pasture, and corn silage. Applying this budget directly to Central Piedmont farming conditions presents a slight problem because coastal bermuda grass pasture is not common in this area. However, the specialists who prepared this budget indicated that pearl millet pasture is an acceptable substitute for coastal bermuda grass pasture when fed at the same level.

The beef herd nutrient requirements reported on the per-acre basis in Budget #20-2 were converted to per-animal requirements reported on a per-ton basis using the yields assumed in other Agricultural Extension Service budgets. These individual animal nutrient requirements were aggregated for a 50-cow cow-calf herd. Thus, the nutritive needs for the entire herd are met by 150 tons of hay-equivalent from ladino clover and grass pasture, 32.5 tons from fescue pasture, and 32.5 tons from pearl millet pasture supplemented by 140 tons of corn silage.

The crop activities required by the beef herd are linked in Table 8 by balance rows 29, 32, 33, and 34 with an X prefix in herd column "COWCF". The figures in these rows represent net per-acre yields utilized by the beef herd, after allowance for animal harvesting loss for the three pasture crops and storage and feeding loss for corn silage. Recall that pasture crop yields are measured in terms of tons of hay-equivalent. Thus, one acre of fescue pasture ("FESPT") makes available 2.275 tons of hay-equivalent, which is transferred by row 29 "XFP" to the beef herd.

Beef Weight Conversion and Marketing Activities

The cow-calf beef herd produces four different outputs: 525-pound steers, 475-pound heifers, 750-pound open cull replacement heifers and 1000-pound cull brood cows. Each of these animal types has its own marketing activity denoted by an "M" prefix in Table 8, columns 35-38. Three animal types listed above move directly from the cow-calf herd activity, "COWCF", to the respective animal culling activity. The model explicitly states the number of animals provided per 50 cow-calf unit herd to be subjected to the culling activity associated with each animal type. Thus, 22.5 steers per herd are moved by balance equation 55 "NMBSTR," 10.5 heifers per herd are moved by balance equation 56 "NMBHF," and 7 cull cows per herd are moved by balance equation 58 "NMCLCO."

Each of the beef animal marketing activities, "M525ST," "M475HF," "MHFCUL," and "MCOW," carries a negative entry in the objective row. This is the marketing charge, calculated at 3% of gross sales value, associated with transferring one animal from the cow-calf herd to the individual animal culling activity. Revenue generated by animal sales is discussed in the next section.

<u>Beef Sales Activities</u>

In this model, all beef animals are marketed in hundred-pound units. This disaggregation of numbers and weight allows much greater insight into how changes in individual animal price, yield, and costs influence overall beef enterprise returns and the competitive position of the cow-calf beef herd relative to the competing enterprises. The sales activities with a "B#" prefix in columns 39-42 of Table 8 receive beef poundage from the individual beef animal marketing activities. These transfers are accomplished by balance equations 59-62 with a "BWT" prefix. For example, animal marketing activity "M525ST" makes available 5.25 hundred-pound units of beef steer, which in turn are moved by balance equation "BWTSTR" to sales activity "B#STR." An analogous set of rows and columns provides for marketing 475-pound heifers, 750-pound cull heifers, and 1000-pound cull brood cows.

Dairy Herd Activities

Dairy Herd Overview

This model assumes that the dairy enterprise is comprised of 1400-pound mature Holstein cows, producing annually 15,000 pounds of milk containing 3.7% milkfat. Milk production takes place over a 305-day lactation period with a subsequent 60-day dry period. Average stage in lactation is 180 days in milk.

The farmer is assumed to raise all replacements for dead and culled cows. No limit on dairy barn capacity is assumed. In the short run, the farmer attempts to maintain the herd at some stable, optimal number of cows over time, since any number of cows less than the optimum represents foregone profits (assuming dairy cows are indeed profitable).

The replacement dairy heifers are divided into three age groups for planning and management purposes: calves between one week and six months old; open heifers seven to fifteen months old; and bred heifers sixteen to twenty-four months old. The number of animals in each age group is specified relative to the number of cows. Coefficients used to express the fraction of young animals per age group per cow come from the midpoint of that particular age group. For example, there are approximately .369 six-month old calves (animal-equivalents) per one cow but only .363 fifteen-month old heifers per cow. This model expresses the fraction of calves expected per cow at 10.5 months of age (.366 calves/cow).

It is also important to note that the number of culls and deaths experienced by the replacement herd is a function of the number of "animal-equivalents" in the replacement herd over the course of one year, not the number of animals present in a particular age group at any one time. For example, a dairy herd may have 60 heifer calves flow through the under-6-months age group per year, but possess a stock of only 30 animals in that category at any one time.

Reproductive and culling rates must be taken into account in such a way that herd size as well as the number of animals in each age class remains constant from one time period to the next. The mature cows experience 2% mortality and 32% culling rates, which are typical of those found in research reports (e.g., Pearson and Freeman), annual reports of the North Carolina Dairy Herd Improvement Association and dairy budgets prepared by North Carolina Agricultural Extension Service personnel. Under these assumptions the number of dairy herd replacements due to calve at twenty-four months of age, on average, will equal the number of mature cows that are culled or died. This balance is in keeping with the farmer's goal of maintaining some constant number of animals in the dairy herd.

Composition and Age Distribution of Dairy Herd

To estimate feed requirements for a dairy herd, it is necessary to specify the age distribution of the animals present at any one time. This distribution is sensitive to assumptions about birth, death, and culling rates for various groups. This section examines the underlying assumptions of the model relating to herd age distribution and describes how the assumed transition rates from one age group to the next may be translated into a linear programming format.

From the outset, this model assumes that 82% of the milking herd experience live births in any twelve-month period. This figure reflects both the failure to achieve a 100% conception rate among the mature cows and a calving interval greater than twelve months. Longer calving intervals can be accommodated by lowering the assumed birth rate.

In accounting for the number of heifer calves between one day and six-months-old present at any one time, calves born to first-calf heifers make up for those not born to those cows culled from the herd. It is assumed that cows to be culled are milked until late lactation when they are no longer profitable and are replaced immediately by a freshly calved heifer. Under this assumption the calves of freshening heifers are incorporated into the 82% figure.

It is assumed that of the live births, 50% are bull calves and are sold immediately at 80 pounds. All heifer calves are retained and assumed to suffer a 10% death loss between birth and six months of age, of which 9% occurs in the first three months. These rates are taken from unpublished North Carolina heifer calf mortality survey data collected by I. D. Porterfield of the Department of Animal Science at North Carolina State University. Annualized death rates for heifers between seven and fifteen months old and bred heifers between sixteen and twenty-four months old are assumed to be 2%. Heifers are bred at fifteen months, and enter the milking herd as replacements at twenty-four months. However, 5% of the animals bred fail to conceive, and are culled at 1100 pounds. In this model, mortality and culling rates for young stock are percentages expressed on a per-cow basis.

The optimal number of milking cows is subject to various resource constraints and competition from other farm-level enterprises. This in turn dictates the number of young female calves born and retained for the milking herd. The young calf population is modified by the appropriate culling and death rates to arrive at the correct number of seven- to fifteen-month old open heifers and bred heifers aged sixteen to twenty-four months.

The programming model jointly considers the various demands made on the farm's scarce resources by both the milking herd and the replacements when selecting the optimal size of the milking herd (Table 9 columns 43-47). Replacement dairy animal control rows 63-66 labeled with prefix "DH" determine the movement of animals between column activities "COW" (mature dairy animals), "CALF" (heifer calves one week to six months old), "HEIF" (open heifers between seven and fifteen months of age), and "BRHF" (bred heifers aged sixteen to twenty-four months). These rows fix the number of young animals in a particular age group relative to the number of cows.

Explanation of the transition rate coefficients used in the model's replacement animal control rows may be of some interest. Control row 64 "DHCALF" makes available .373 heifer calves under six months of age per mature dairy cow. This transition rate is simply the product of the assumed live-calf crop percent, the female calf rate, and the three-month survival rate (i.e., .82 x .50 x .91). In turn, row 65 "DHOPHF" measures the number of open heifer calf animal-equivalents relative to the number of animals in the "COW" category. Similarly, replacement animal control row 66 "DHBRHF" describes the number of bred heifer animal-equivalents relative to the number of milk cows. Dairy cow death losses appear in replacement animal control row 63 "DHDEAD," which moves 2% of the entire milking herd into the dead cow disposal activity "DCDIE" to provide a full accounting of all losses during any twelve-month period.

Table 9. Dairy herd inventory and sales

Row number	Row ID	Number of head COW 43	DCDIE 44	CALF 45	HEIF 46	BRHF 47	ICOW 48	ICALF 49	Inventory IOHEF 50	IBRHF 51
OBJ. ROW		-295	0	-151.9	-65.17	-68.08				
63	DHDEAD	-.02	1							
64	DHCALF	-.373		1						
65	DHOPHF	-.366			1					
66	DHBRHF	-.3425				1				
67	INCOW	-1					1			
68	INCALF			-.5				1		
69	INOPHF				-.75				1	
70	INBRHF					-.75				1
71	NMCOW	-.32								
72	NMCALF	-.41								
74	NMBRHF	-.0182								

Row number	Row ID	Animals marketed CCOW 52	CCALF 53	CBRHF 55	Hundredweight sold D#COW 56	D#CALF 57	D#BRHF 59	RHS
OBJ. ROW		-16.8	-.84	-13.2	40	35	40	MAX
63	DHDEAD							= 0
64	DHCALF							>= 0
65	DHOPHF							>= 0
66	DHBRHF							>= 0
67	INCOW							= 0
68	INCALF							= 0
69	INOPHF							= 0
70	INBRHF							= 0
71	NMCOW	1						<= 0
72	NMCALF		1					<= 0
74	NMBRHF			1				<= 0
75	DWTCOW	-14			1			<= 0
76	DWTCLF		-.8			1		<= 0
78	DWTBHF			-11			1	<= 0

The number of animals reported in each of the dairy replacement animal categories is interpreted as the number of "animal-equivalents" that have flowed through the dairy herd during the one-year plannning period. The stock of animals present at any one time is calculated by the model using the four transfer rows 67-70 with the "IN" prefix and the four accounting columns 48-51 with an "I" prefix. Thus, young heifer "animal-equivalents" are multiplied by .5, and open heifer "animal-equivalents" and bred heifer "animal equivalents" by .75 to arrive at the proper number of animals. These calculations result in a ratio of .72 replacement animals per mature dairy cow. This result is consistent with optimal planning figures published by Burton et al.

Dairy Weight Conversion and Culling Activities

As discussed above, culling decisions are made within the dairy herd at three different ages. This model partitions these dairy culling decisions and animal sales activities into two separate, distinct sections. Culled animals are moved from their respective herds to individual animal culling weight conversion activities 52-55 ("C" prefix in Table 9) by balance equations 71-74 with the "NM" prefix. Balance equation 71 "NMCOW" transfers 32% of the dairy cow population to a cull cow sales activity "CCOW." The rate at which bull calves are culled per milking cow per year is the product of the live-calf percentage and the percent of male births. These rates are .82, and .50, respectively, leading to a rate of .41 cull bull calves per milking cow per year. This relationship is captured in the model by balance equation 72 "NMCALF." Note that all culled animals are assessed a marketing charge of 3% of gross sales value. This is a negative figure found in the objective row because it is subtracted from variable profit.

Cull dairy animal sales activities, columns 56-59 in this model and designated by prefix "D#" in Table 9, are measured in hundred-pound sales units instead of the single animal units used in the dairy culling activities. For each of the cull animal types (i.e., mature dairy cow, week-old bull calf, and fifteen-month-old open heifer), a balance equation links the appropriate culling number and sales weight activities.

Balance equations 75-78 ("DWT" prefix) transfer hundred-pound increments from the animal-based culling activities to the weight-based sales activities. Fourteen hundred-pound units of cull dairy cow are transferred from culling activity "CCOW" to cull sales activity "D#COW" via balance equation 75 "DWTCOW." Row 77 "DWTHEF" takes the 6.5 hundred-pound units made available by culling one 15-month old open heifer in culling activity "COHEF," and transfers it to cull animal sales activity "D#OHEF." Once these transfers occur, the animal is sold in hundred-pound increments at the hundred-pound price indicated in the objective row.

Dairy Herd Nutrition

Nutrient demands of the milking herd reflect 12-month feeding requirements for a mature 1400 pound Holstein cow producing 15,000 pounds of 3.7% milk over a ten-month period. She is assumed dry and pregnant over the remaining two months. Feeding requirements for replacements are specified for animals achieving the following daily gains in body weight in the specified time period: between 1.4 and 1.8 pounds from birth until six months of age; 1.8 pounds between seven and fifteen months; and 1.6

pounds from sixteen months until calving at twenty-four months of age at a weight of 1150 pounds.

Requirements associated with replacements reflect one "animal-equivalent" being fed for a 12-month period. However, this does not mean that the <u>same</u> animal is being fed for all twelve months. For example, the nutrient requirements found in the model under "CALF" reflect those needed to feed two calves from birth to six months or one animal of the same age for an entire 12-month period. Similarly, the nutrient demands of a bred heifer fed from 16 to 24 months, a nine-month period, are multiplied by a factor of 1.33 to reflect the needs of the same animal type for an entire year.

Animal nutrition is an important element of any dairy herd model. This model assures that all major National Research Council nutrient requirements are met or exceeded. The feeding program for all dairy stock up to twenty-four months of age follows recommendations made in North Carolina Agricultural Extension Service Budget #10-4 (Appendix Table 4). Feeding requirements for the lactating cows and dry cows are met on a least-cost basis. Minimizing cost for a given nutrient level is in keeping with the model's overall goal of maximizing variable net profit (Feitshans).

The least-cost balanced ration was generated using a computer program extracted from "DART," the utility software system available through the Southeast Dairy Records Processing Laboratory that provides <u>D</u>irect <u>A</u>ccess to <u>R</u>ecords by <u>T</u>elephone (DART). Dr. Lon Whitlow, Agricultural Extension Service dairy specialist in the Department of Animal Science, North Carolina State University, developed the stand-alone capability for the program. Choosing from a group of sources consisting of pasture forages harvested by the cow, various home-produced silages, several different types of hay, and purchased minerals and concentrates, and guided by known per-unit feed costs, the computer program balanced twelve separate nutrient requirements subject to any feeding restrictions imposed by the farmer.

Several feeding strategies were imposed on calculations for the optimal dairy ration. Chief among those were the assumptions that all concentrates and minerals are purchased and that lactating cows do not have access to pasture. Under typical Central Piedmont farm conditions, cows in lactation receive a very small proportion, if any, of their nutrients from pasture. This is due in large part to seasonal and wide year-to-year variations in pasture yields experienced by North Carolina dairymen. However, in this model, pasture is assumed available to the dry cows. Other restrictions involved constraining certain ingredients to designated maximum percentages of the concentrate mix and adjusting certain animal dietary requirements to reflect production agriculture conditions more accurately.

Ration formulations are external to the linear programming model. The optimal daily rations computed were converted to a twelve-month basis and entered as dairy animal nutrient demands in the appropriate "X" balance row of the model (Table 10). It was found that the optimal feeding strategy included 7.915 tons of corn silage per cow per one-year period, fescue pasture in season for dry cows, fescue hay and 3.184 tons of purchased concentrates. These values are entered as positive entries in balance rows 29, 34, 37 and 79 under column activity "COW."

Table 10 . Dairy herd nutrition, milk production and sales

Row number	Row ID	Purch. conc. feed 60	Dairy herd requirements COW 43	CALF 45	HEIF 46	BRHF 47	Milk sales CLSI 61	CLSII 62	RHS
OBJ. ROW		-142.50	-295	-151.90	-65.17	-68.08	14.50	10.43	MAX
1	LABOR		63.9	24	14	10			<=5113
29	XFP		.5971		1.955	2.666			<= 0
34	XCS		7.915		1.833	2.5			<= 0
37	XFH		1.226	.5	1.3	1.1			<= 0
79	XFEED	-1	3.184						<= 0
80	MLKSL		-150				1	1	<= 0
81	CLASUT						.2	-.8	<= 0

The cost figures used in calculating the least-cost ration are of some interest. Costs of purchased concentrates reflect those prevailing in the Central Piedmont region in mid-1987. Per-acre costs of feedstuffs grown on the farm were derived from Agricultural Extension Service budgets. These production costs reflect both fixed and variable costs, excluding labor charges. It was felt that this procedure more accurately gauged the true cost of production for home-grown crops. These per-acre costs were in turn divided by the adjusted net per-acre yield to get the per-ton cost of home-grown feedstuffs. This structure makes it relatively easy to change cost or yield assumptions and to observe the resulting effects on the least-cost ration formulated and on the associated optimal enterprise combination for the entire farm.

Objective Row Values for Dairy Enterprise

The activities included in the dairy enterprise are: "CALF" (heifer calf less than 6 months old), "HEIF" (open heifer between 7 and 15 months old), "BRHEF" (bred heifer between 16 and 23 months old), and "COW" (mature milking animal). The objective row value for each enterprise represents the annualized non-labor, non-feed, non-capital variable operating costs attributable to one animal in that category. Appendix Table 5 lists the budgeted items and associated costs for the milking herd. These costs reduce the variable profit of the entire farm, and thus, carry a negative sign. The variable operating costs for the young stock were derived from values reported in North Carolina Agricultural Extension Service Budget #10-4. These costs were adjusted to reflect one animal-equivalent maintained for a twelve-month period. Labor requirements for each animal type are entered in row 1 of Table 10.

Milk Production and Marketing

Each cow in the milking herd is assumed to produce annually 15,000 pounds of milk with a 3.7% fat content. All milk produced is either marketed as Class I fluid milk or as lower-priced Class II manufacturing sales. The milk producer is subject to a class utilization constraint on Class I sales to no more than 80% of all sales. The selected milk yield, milk fat percentage and class utilizations are typical of the current situation in the North Carolina dairy industry.

The above situation requires balance equation 80 "MLKSL" to move the 150 hundred-pound units of milk per cow to Class I sales activity "CLSI" or to Class II sales activity "CLSII" in hundred-pound sales units as shown in Table 10. "CLSI" and "CLSII" milk sales bring prices of $15.50 and $11.43, respectively. However, these prices must be adjusted for a combined milk transportation and marketing charge of $1.00 per hundred pounds, which results in net sales prices of $14.50 for Class I milk, $10.43 for Class II milk, and a blend price of $13.68. Row constraint 81 "CLASUT" maintains the class utilization rates outlined above. This is accomplished by entering the maximum Class I utilization rate in the Class II column with a negative sign and the Class II utilization rate (1 - Class I rate) in the Class I column with a positive sign.

Separate treatment of the milk production and marketing activities permits marginal valuation of changes in class prices, class utilization rates or per-cow milk production figures. This structure provides insight into the competitive position of the dairy enterprise under varying assumptions regarding these technical coefficients.

III. OPTIMAL ENTERPRISE COMBINATIONS ON REPRESENTATIVE FARM

This section presents the optimum combination of enterprises on a representative farm in the Central Piedmont of North Carolina. The impact of fixed costs associated with the dairy herd on net profit is shown. The sensitivity of the optimum plan to changes in the level of milk and beef prices, labor supply, land availability and technical coefficients are investigated.

Base Resource Farm Plan

The resources found on the representative farm are listed in Table 11. Note that 190 total acres of land are available. It is assumed that all land can support pasture crops, but only 140 acres can sustain row crops. Cropland and pasture may be rented at $40 and $15 per acre, respectively. In the following discussion, the resource base presented in Table 11 shall be referred to as the "base farm plan."

The optimal enterprise combination includes wheat and dairying but no beef or off-farm work. Variable profit is $76,332. The wheat enterprise, which contains approximately 18.5 acres, is grown on owned row-crop land. Dairy herd inventory and sales, forage production and concentrates purchased are shown in column two. All owned row-crop land and pasture are used. Owned row-crop land is used to grow row crops. No row-crop land and only 33.4 acres of pasture are rented.

The dual values of binding resource constraints shown in the last column provide more insights into the optimal enterprise combination.

Table 11. Optimal enterprise combination for representative farm

Item	Unit	Maximum available	Optimal level	Cost or price (dollars)	Dual value (dollars)	Value of add. unit[a] (dollars)
Variable Profit	Dollars		76332			
Dairy Herd Inventory						
Milk Cows	Head		85.2			362.42[b]
Bred Heifers	Head		21.9			
Open Heifers	Head		23.4			
Heifer Calves	Head		15.8			
Outputs						
Milk Sales:						
Class I	Cwt.		10224	14.50		
Class II	Cwt.		2556	10.43		
Dairy Herd Sales:						
Bull Calves	Head		34.9			
Cull Cows	Head		27.3			
Cull 15-Mo. Heifers	Head		1.6			
Wheat	Acres		18.53[c]			
Owned Inputs						
Owned Cropland[c]	Acres	140				
Fescue Hay	Acres		56.07			
Corn Silage	Acres		65.40			
Owned Pasture	Acres	50				
Fescue Pasture	Acres		50.00			
Total Land	Acres	190	190.00			
Family Labor	Hours	5113	5113	0	11.56	11.56
Purchased Inputs						
Rented Cropland	Acres	95	0	40.00	25.66	-14.34
Rented Pasture	Acres	35				
Total Land	Acres	130	33.35			
Hired Labor	Hours	2550	2550	6.50	11.56	5.06
Concentrates	Ton		271.3			
Non-selected Enterprises						
Off-Farm Work	Hours	2000	0	5.50	11.56	-6.06

[a]For limiting resources, this is the difference between dual value and input price. For non-limiting resources, input price must be reduced by this amount for resource to enter basis. For non-selected enterprises, this represents output price disadvantage.

[b]Calculated as change from 84.2 to 85.2 head.

[c]Wheat grown on owned cropland.

The optimal dairy herd is comprised of 85.2 dairy cows. In a separate computer run, the number of dairy cows was constrained to exactly one less animal or 84.2, effectively becoming a binding restraint. This exercise provided a shadow price or dual value for dairy cows of $ 362.42. This value should be interpreted as the variable profit provided by the addition of one dairy cow at the margin. The dual value of the hired labor constraint is $ 11.56, indicating high returns to additional labor. The value of additional cropland is $14.34 below the cash rental rate.

Inclusion of Dairy Herd Fixed Costs

A separate computer run was made to determine the effect of assigning a specified per-cow fixed cost on profitability of the dairy enterprise. Fixed cost figures come from the machinery and equipment inventories listed in Appendix Tables 1 and 2. These values were modified using an interest rate of 7%. Approximate per-cow fixed cost was $300 and was assumed constant as herd size expanded. This value was added to the per-cow variable cost of $295 in the objective row. The resulting optimal enterprise combination was identical to the original solution. However, variable profit decreased from $76,332 to $50,773 and the dual value of additional labor dropped from $11.56 to $8.13.

Sensitivity to Level of Milk and Beef Prices

The sensitivity of the optimal enterprise combination for the base farm resource plan was examined using price-mapping techniques. Price-mapping provides a convenient way to examine how the optimal enterprise combination level and mix varies as two input or output prices are varied simultaneously. Various optimal enterprise combinations are represented by corresponding areas on the price map. Tomek and Robinson (p.355), for example, note that "by using price-mapping techniques, boundary prices (those at which alternatives are equally profitable) could be readily identified."

Output prices for the milk and beef enterprises were selected as variables for price-mapping because these two items are deemed to be major factors determining optimal enterprise combinations. The relevant ranges of prices used for each enterprise in this analysis were selected based on historical price patterns, consultation with personnel at North Carolina State University, and alternate assumed prices of analytical interest.

Output price for milk is reported as a net blend price, reflecting a $1 per hundredweight assessment on both Class I and Class II products for marketing, promotion, and hauling. Base milk prices before allowance for deductions are $15.50 for Class I and $11.43 for Class II. After deductions, net blend price received by farmers is $13.68, reflecting an 80% Class I utilization rate and a 20% Class II utilization rate. As milk price is changed in the price-mapping analysis, the differential between Class I and Class II products is maintained at a constant $4.07. The various milk prices used in this analysis are reported in Appendix Table 8.

The overall profitability of the beef cow-calf herd is determined by the prices received for four separate outputs including steer calves, heifer calves, cull heifers, and cull cows. For this analysis, it was assumed that all beef prices moved together by the same dollar increment, thereby maintaining the same price differential found in the base set of prices. These prices per live hundredweight are $72 for steer calves,

$62 for heifer calves, $55 for culled heifers, and $42 for culled cows. The dollar amounts received for each animal type at the different assumed price levels are listed in Appendix Table 9.

Results of the price mapping analysis are presented in Figure 2 and Table 12. These results suggest that the initial optimal enterprise combination is relatively insensitive to upward changes in the output prices of both the beef and dairy enterprises. Also, it appears that given initial land and labor levels, milk dominates beef and cash crops over a wide range of prices. At base beef prices, the net blend milk price was required to drop between $2 and $3 per hundredweight before the beef enterprise entered the optimal solution. Thirty dairy cows were replaced by 16 cow-calf units and an additional 40 acres of wheat.

Wheat was the only cash crop that entered the optimal enterprise combination during this analysis. Wheat is not particularly labor intensive; thus, when net milk price fell below $10.68 and beef price was almost any level, off-farm work entered the optimal enterprise combination at the highest level allowed in this model (2000 hours).

With the base net blend milk price of $13.68 and base beef price of $72 per live hundredweight, the beef enterprise did not enter the optimal enterprise combination. All beef animal prices had to rise between $5 and $10 to enter the optimal enterprise combination. Even at these relatively high price levels, the beef enterprise only entered the basis at an impractical level of one cow-calf unit. Only 10 cow-calf units are in the optimal enterprise combination at base milk prices and the highest available beef price ($87 per live hundredweight of beef steer). At higher milk

Figure 2. Price map of optimum enterprise combinations, varying prices of milk and beef, Central Piedmont, North Carolina[a]

Price Received per Hundred Pounds of Beef Steer[b] (dollars)	8.68	9.68	10.68	11.68	12.68	13.68	14.68	15.68	16.68	17.68
87	D	D	D	G	G	F	F	A	A	A
82	D	D	I	F	F	E	A	A	A	A
77	D	D	H	E	E	A	A	A	A	A
72	D	C	B	A	A	A	A	A	A	A
67	C	C	J	A	A	A	A	A	A	A
62	K	K	J	A	A	A	A	A	A	A
57	L	L	J	A	A	A	A	A	A	A
52	L	L	J	A	A	A	A	A	A	A
47	L	L	J	A	A	A	A	A	A	A
42	L	L	J	A	A	A	A	A	A	A

Net Blend Price Received per Hundred Pounds of Milk[c]
(dollars)

[a]Letters in price map correspond to different optimum combinations. See Table 12 for details.

[b]Other beef animal prices varied simultaneously, See Appendix Table 9 for details.

[c]See Appendix Table 8 for corresponding Class I and Class II prices. Assumes 80% Class I utilization rate and 20% Class II utilization rate.

Table 12. Optimal combination of enterprises under varying milk and beef prices, base resource plan

Enterprise combination	Enterprise level: Dairy cows (head)	Cow-calf beef (head)	Wheat (acres)	Off-farm work (hours)
Base beef price:				
A	85.2	0	18.5	0
B	54.1	16.1	59.3	0
C	29.7	28.0	91.3	2,000
D	19.5	122.6	0	2,000
High beef price:				
E	85.1	1.0	18.5	0
F	84.3	10.1	0	0
G	78.1	59.4	0	0
H	51.4	45.5	0	0
I	45.3	94.8	0	0
Low beef, low milk prices:				
J	56.0	0	60.1	0
K	32.0	9.3	92.2	2000
L	33.2	0	92.7	2000

prices, only these extraordinarily high beef prices allowed the beef enterprise to enter the optimal enterprise mix.

Between 1982 and 1987, annual average steer and heifer prices ranged between $46.60 and $58.60 per hundredweight in North Carolina. Given these historic beef prices, dairy farming competitiveness diminished significantly only when the net blend milk price was lower than $10.68. Successive lowering of net blend milk price in this analysis resulted in rapid resource transfer from dairying to the wheat enterprise and off-farm work.

Sensitivity to Resource Availability

This section discusses how the optimal enterprise combination on a representative Central Piedmont farm is altered in response to specific changes in resource availability. Recall that the optimal enterprise combination refers to the set of enterprises that yields the highest variable profit, given available land and labor and other specified restrictions.

The following changes in resource availability were programmed for the representative farm: (1) variation in the level of land and labor resources provided by the farm owner-operator and his family; (2) changes in the amounts of cropland and pasture available for rental by the farm owner-operator; (3) variation in the amount of hired labor available for farm work, including the lifting of all hired labor constraints; and (4) elimination of all rented land and hired labor. These four changes involve revising the right-hand side values of the linear programming model.

Family Labor

The amount of unpaid family labor available to the farm enterprise was varied from 1288 to 8938 hours. Since one man-year of labor is defined here as 2550 hours of labor, up to 1.5 man-years of labor were added to or subtracted from the base plan amount of 5113 hours. All other resources were maintained at levels found in the base farm plan. Variable profit and herd size were found to be highly sensitive to the supply of family labor (Table 13). Herd size ranged from 41.5 to 128.2 cows and variable profit from $32,000 to $118,900 as family labor supply increased.

One issue of interest is the cash flow associated with the various optimal enterprise combinations. Variable profit less debt ervice provides one measure of cash flow available for asset replacement and family living expenses. Total debt service payment per farm was calculated as the product of the number of dairy cows and the average annual debt payment per cow. Average 1985 debt payment reported in the Dairy Farm Business Summary was $316 per cow (Benson and Sutter, 1987, p. 43). Using this value, debt service payment and cash flow calculated for each family labor situation are reported in Table 13.

Hired Labor

Availability of hired labor was raised from zero to two man-years of labor. A special case entailed lifting all hired labor contraints facing the representative farm. This latter resource situation asssumes a perfectly elastic supply of labor at the going market price of $ 6.50 per hour. Variable profit and herd size were found to be sensitive to the availability of hired labor (Appendix Table 11).

Table 13. Cash flow by level of family labor supply

	Hours of labor provided by family						
Item	1,288	2,563	3,838	5,113	6,388	7,663	8,938
Variable profit (dollars)	31,983	46,860	61,596	76,332	90,721	104,818	118,915
Debt service payments (dollars)	13,114	17,696	22,310	26,923	31,505	36,024	40,511
Cash flow (dollars)[a]	18,869	29,164	39,286	49,409	59,216	68,794	78,404

[a]Amount available for asset replacement and family living expense before allowance for fixed costs.

As shown in Figure 3, when total labor supply increases by adding family labor while holding hired labor at 2550 hours, variable profit increases by first $11.56 per hour and then $11.06 within the range found in Table 13. However, when family labor is held constant at 5113 hours per year, variable profit increases at $5.06 per hour of hired labor. This difference reflects the hired labor wage rate of $6.50 per hour. Herd size increases with total labor supply whether provided by family or by hired labor.

Owned Farmland

The total amount of owned farmland was varied from 90 to 290 acres. As total land owned was constrained or expanded, the approximate 3-to-4 ratio of cropland to total land was maintained as in the base farm plan. Thus, a 50-acre reduction in total land owned implies a 37.5-acre decrease in potential cropland and a 50-acre decrease in land capable of growing pasture.

Land levels analyzed included 90, 140, 190, 240, and 290 acres. Neither variable profit nor herd size was greatly affected, although the wheat enterprise expanded on larger farms (Table 14). This result emphasizes the critical role of labor supply, which was held at the base level of 7663 hours.

A special situation of no owned farmland was also modelled. In this situation, rental land availability becomes a constraint, off-farm work enters the plan and variable profit decreases.

FIGURE 3. RELATIONSHIP BETWEEN HIRED LABOR, FAMILY LABOR AND VARIABLE PROFIT

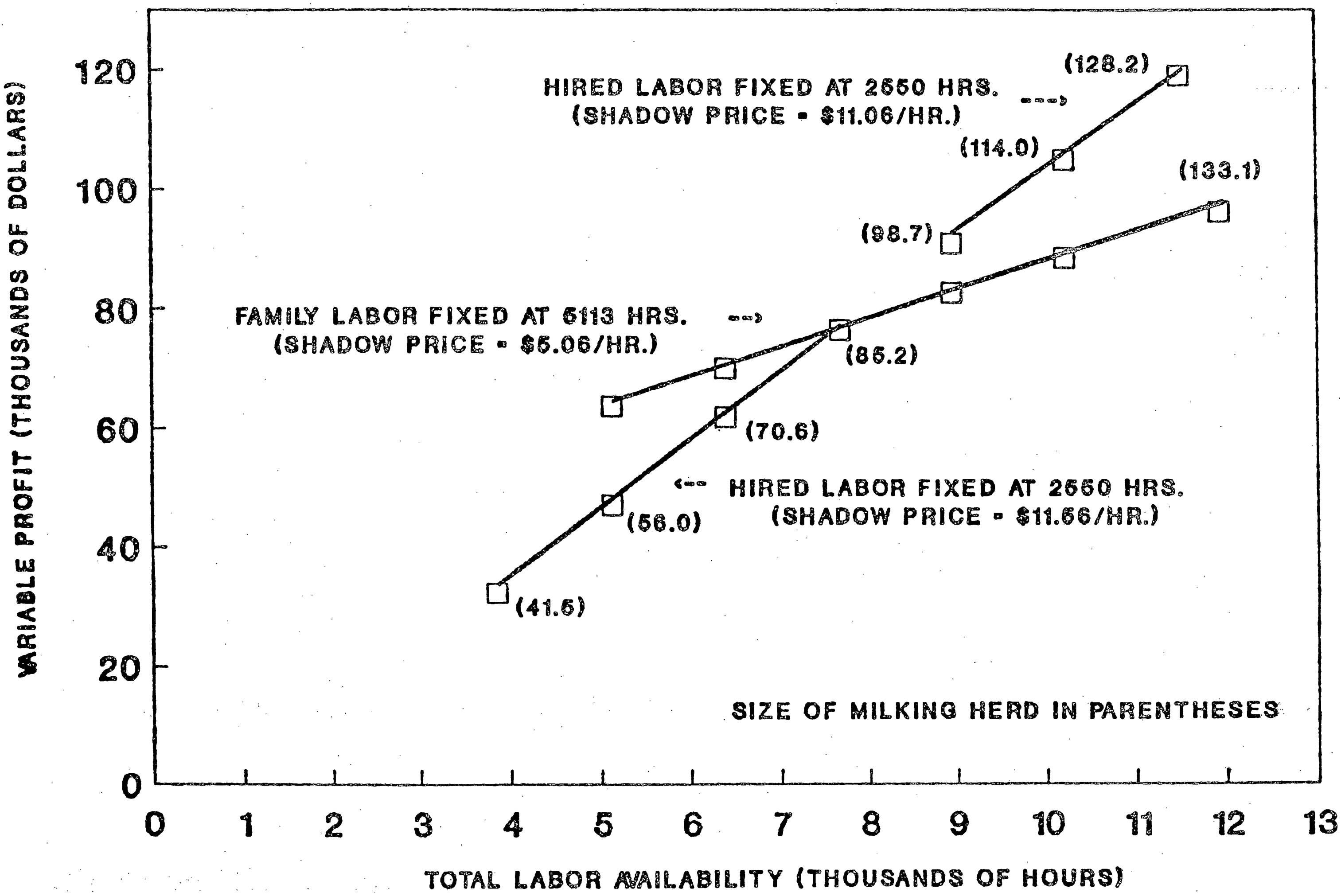

Table 14. Optimal enterprise combination by total acres of owned farmland

Item	Unit	Total acres of owned farmland					
		0	90	140	190	240	290
Variable profit	Dollars	55,922	72,624	74,624	76,332	77,481	78,631
Variable profit: Change from base plan	Dollars	-20,410	-3,708	-1,708	BASE	+1,149	+2,299
Enterprise levels:							
Dairy cows	Head	54.1	85.5	85.5	85.2	84.5	83.9
Beef cow-calf	Units	0	0	0	0	0	0
Wheat	Acres	0	0	0	18.5	56.9	95.4
Off-farm work	Hours	267.1	0	0	0	0	0
Owned land used:							
Pasture	Acres	0	25*	37.5*	50*	62.5*	75*
Row-crop land used for crops	Acres	0	65*	102.5*	140*	177.5*	215*
Row-crop land used for pasture	Acres	0	0	0	0	0	0
Rented land used:							
Pasture	Acres	35	35	35	33.4*	20.2	7.1
Row-crop land used for crops	Acres	77.1	56.9	19.4	0	0	0
Row-crop land used for pasture	Acres	17.9	23.7	11.2	0	0	0
Hired labor used:	Hours	0	2,550*	2,550	2,550	2,550	2,550
Dual value for additional labor	$ per hour	0.00	11.06	11.06	11.56	11.56	11.56
Dual value for additional rented pasture	$ per acre	232.10	25.00	25.00	0.00	0.00	0.00

*Indicates maximum amount of resource available.

Rented Farmland

A change in the amount of rental farmland available to the representative farm was investigated. This involved increasing and decreasing total land available for rental by 50% or 65 acres. Row-crop land was added or deleted in amounts proportional to those found in the base farm plan. Complete elimination of rental land was also modelled. The decline in available rental land reduced available rental pasture and, because the constraint on rented pasture is binding, it was profitable to divert 14.9 acres of owned row-crop land to grow pasture (Table 15). The net effect was to maintain the optimal number of dairy cows at 85.2 and to reduce variable profit by $159. The constraint on hired labor prevented the increased availability of rental land from altering the mix or level of the initial optimal enterprise combination.

Elimination of Rented Land and Hired Labor

The simultaneous elimination of available rental land and hired labor was modelled. This resource situation constrains the farm to the base plan levels of 190 acres of total farmland and 5113 hours of unpaid family labor. All other resources were available in the amounts found in the base plan. Herd size and variable profit were substantially reduced and the optimal enterprise combination is similar to that in Column 2, Table 13.

Sensitivity to Changes in Technical Coefficients

Labor Requirements Per Dairy Cow

Changes in the technical coefficients involve entering new values in appropriate cells of the body of the matrix. As an example, the amount of

Table 15. Optimal enterprise combination by acres of rental land availability

Item	Unit	Total acres of rental land available 0	65	130	195
Variable profit	Dollars	73,104	76,173	76,332	76,332
Variable profit: Change from base plan	Dollars	-3,328	-159	BASE	+0
Enterprise levels:					
Dairy cows	Head	79	85.5	85.2	85.2
Beef cow-calf	Units	0	0	0	0
Wheat	Acres	0	3.3	18.5	18.5
Off-farm work	Hours	0	0	0	0
Owned land used: Pasture	Acres	50*	50	50	50
Row-crop land used for crops	Acres	112.7	125.1	140*	140
Owned row-crop land used for pasture	Acres	27.3	14.9	0	0
Rented land used:					
Pasture	Acres	0	18.8	33.4	33.4
Row-crop land used for row crops	Acres	0	0	0	0
Row-crop land used for pasture	Acres	0	0	0	0
Hired labor used:	Hours	1,969.4	2,550*	2,550	2,550
Dual value for additional labor	Dollars	0	11.44	11.56	11.56

*Indicates maximum amount of resource available.

labor required per cow was revised. In the base plan, 63.9 hours of labor are required per mature dairy animal. New labor coefficients considered were 31.9, 47.9, and 79.9 hours per cow. The first two cases effectively increase the amount of available labor on the farm. As would be expected, in both situations the dairy enterprise expanded, and the farm variable profit increased (Table 16). On the other hand, with the dairy herd requiring more labor, it is in effect less competitive. Under these conditions, wheat acreage expanded at the expense of the dairy herd.

Corn Silage Yield

Corn silage yield, adjusted for storage and feeding losses, was changed from 12.3 tons per acre in the base case to 6.15 tons per acre and to 18.45 tons per acre. This represents a 50% variation in the per-acre yield found in the base plan. The change in yield in turn alters the per-ton cost of production. These different per-ton costs were then used by the "DART" computer package to develop a new least-cost ration for the milking herd appopriate to the changed economic circumstances. The technical coefficients from the resulting rations were then placed in the linear programming whole-farm planning model. Note that the feeding program for the dairy replacement animals follows guidelines suggested in budgets prepared by the North Carolina Agricultural Extension Service, and thus was not altered as corn silage yields changed.

The initial least-cost ration for lactating cows included fescue hay, corn silage, and 21% crude protein concentrate. The dry cow ration consisted of fescue pasture and/or fescue hay, and small amounts of 15 %

Table 16. Optimal enterprise combination by labor efficiency

Item	Unit	Annual hours of labor required per dairy cow: 31.9	47.9	63.9	79.9
Variable profit	Dollars	121,432	95,039	76,332	63,014
Variable profit: Change from base plan	Dollars	+45,100	+18,707	BASE	-13,318
Enterprise levels:					
Dairy cows	Head	130.7	104.1	85.2	72
Beef cow-calf	Units	0	0	0	0
Wheat	Acres	0	0	18.5	37.3
Off-farm work	Hours	0	0	0	0
Owned land used:					
Pasture	Acres	50*	50	50	50
Row-cropand used for crops	Acres	97.1	123.2	140*	140
Owned row-crop land used for pasture	Acres	42.9	16.8	0	0
Rented land used:					
Pasture	Acres	35*	35	33.4	20.5
Row-crop land used for row crops	Acres	89.3	25.1	0	0
Row-crop land used for pasture	Acres	0	0	0	0
Hired labor used:	Hours	2,550*	2,550*	2,550	2,550
Dual value for additional labor	Dollars	16.90	13.46	11.56	9.77

*Indicates maximum amount of resource available.

crude protein concentrate. The appropriateness of the mix and level of each ingredient in the least-cost ration was confirmed by animal nutrition specialists at North Carolina State University.

With the 50% increase in per-acre corn silage yield and the resulting per-ton cost reduction, increased amounts of corn silage completely replaced fescue hay in the least-cost milker ration. Increased availability of corn silage similarly replaced fescue pasture in the least-cost dry cow diet. In both instances, increased amounts of a more costly higher protein concentrate were required to balance the lower protein content of corn silage. The increase in concentrate use was more than offset by the cost savings stemming from the lower-cost corn silage resulting in an increase of $8,941 in variable profit (Table 17).

With the lower corn silage yield, increased production of fescue hay completely replaced corn silage in the least-cost milker ration. Also, larger daily amounts of a lower protein concentrate were required in the new least-cost milker ration. In the revised dry cow least-cost ration, slightly larger amounts of a higher protein feed were required. Also, fescue hay replaced corn silage, with fescue pasture present in both rations. The effect was a decrease of $7,735 in variable profit. This method of measuring the effect of crop yield assumptions on variable profit illustrates one use of linear programming. However, it should be recognized that decreases in corn yield might well be accompanied by simultaneous decreases in yields of other crops if caused by unfavorable weather, for example.

Table 17. Effect of corn silage yield on optimal enterprise combination and feed sources

Item	Unit	Silage yield: 50% decrease (6.15 tons/acre)	Silage yield: Base plan (12.3 tons/acre)	Silage yield: 50% increase (18.45 tons/acre)
Variable profit	Dollars	68,597	76,332	85,273
Variable profit: Change from base plan	Dollars	- 7,735	BASE	+8,941
Enterprise levels:				
Dairy cows	Head	83.5	85.2	87.1
Wheat	Acres	18.48	18.52	39.2
Off-farm work	Hours	0	0	0
Owned land used:				
Pasture	Acres	50*	50	50
Row-crop land used for crops	Acres	140*	140	140
Row-crop land used for pasture	Acres	0	0	0
Rented land used:				
Pasture	Acres	31.9	33.4	12.4
Row-crop land used for row crops	Acres	0	0	0
Row-crop land used for pasture	Acres	0	0	0
Hired labor used:	Hours	2,550*	2,550	2,550
Dual value for additional labor	Dollars	10.52	11.56	12.76
Dairy herd feed sources:				
Fescue pasture	Acres	81.9	83.4	62.4
Fescue hay	Acres	100.8	56.1	26.3
Corn silage	Acres	20.7	65.4	74.6
Milker concentrate	Tons	369.6	271.3	219.1

*Indicates the maximum amount of resource available.

IV. SUMMARY AND CONCLUSIONS

This report describes the use of a whole-farm linear programming model for analyzing the competitive position of milk production in the Central Piedmont region of North Carolina. Much of the report is devoted to a detailed presentation of technical coefficients required to investigate the interaction between dairy production and competing enterprises that include forages, cash crops, a cow-calf beef enterprise and off-farm employment.

The model is designed to maximize the net returns to fixed factors assumed available on a typical Central Piedmont farm. Prices and costs are representative of those found in the study area in the mid-1980s. This model makes it possible to investigate the sensitivity of the optimum enterprise combination to changes in milk and beef prices, land and labor supplies, and assumed technical coefficients.

Unique to this study is the method employed to represent the changes in numbers of dairy and beef herd animals by age group. Minimum cost rations are calculated using DART, a computer model adapted for this purpose by animal scientists at NCSU. Product prices, Class I and Class II utilization rates, and technical coefficients are readily modified to investigate the impact of alternative assumptions on the optimum enterprise mix.

The base farm enterprise mix consisted of a dairy herd of 85 milking cows, sale of wheat as a cash crop, production of corn silage and fescue hay for the dairy herd and fescue pasture for young stock and dry cows. Owned cropland of 140 acres was supplemented by 95 acres of rented cropland and the 50 acres of owned pasture was supplemented by an additional 35 acres of rented pasture. Operator and family labor of 5113 hours was supplemented by an additional man-year (2550 hours) of hired labor. Variable profit was calculated at $76,332 per year. Typical debt service payments on a farm of this size were estimated to be $29,923, leaving $49,409 as the amount available for asset replacement and family living expenses before deducting all allowances for fixed costs of buildings and equipment.

In the model, the base price of milk was $13.68 per cwt. after allowance of $1.00 for marketing and hauling charges, and the base steer price was $72 per cwt. When milk price was lowered $3.00 or more per cwt., beef production gradually replaced milk production at the base beef price. Beef production also increased when beef price was raised while holding milk price at $13.68. When milk price was lowered $4.00 and beef prices were lowered $15.00 per cwt., wheat acreage expanded and off-farm work became a profitable activity.

Variable profit and dairy herd size were highly sensitive to family labor supply, increasing to $104,818 and 128 head, respectively, when one and one-half man years were added. On the other hand, restricting owned or rented land availability had only limited effects on herd size, reducing the area planted to wheat. Reductions in labor requirements per cow had the same effect as increasing labor supply. Higher corn silage yield led to the replacement of fescue hay in the milking herd ration and fescue pasture in the dry herd ration.

The sensitivity analyses summarized above demonstrated the importance of selecting appropriate technical coefficients in any analysis of the competitive position of milk production or in evaluating the profitability of dairying as a major enterprise on individual farms. The model developed here is suited to analysis of individual farm adjustment opportunities as long as resource availability and technical relationships accurately reflect specific farm situations.

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VI. Appendix Tables

Appendix Table 1. Annual ownership expenses for specialized dairy herd buildings and equipment

Item	Life (years)	Initial cost (dollars)	Annual ownership expenses (dollars) Depreciation	Interest	Insurance	Taxes	Total
Buildings:							
Barn with 58 free stalls	15	17336	1156.26	780.12	86.24	51.92	2074.54
Heifer barn	15	3160	210.67	142.20	15.80	9.48	378.15
Machine shed	15	2250	150.00	101.25	11.25	6.75	269.25
Milking parlor, double 4	15	17300	1153.33	775.50	56.50	51.90	2070.23
Silo, horizontal	15	8591	570.46	386.59	42.60	28.40	1028.05
Fencing	15	1700	113.33	76.50	8.50	5.10	203.43
Grain bin (5000 bu.)	15	3675	220.50	181.91	20.21	12.13	434.75
Supplement bin	15	400	24.00	19.50	2.20	1.32	47.32
Manure ramp	15	1725	115.00	77.62	8.62	5.18	206.42
Retention bond	15	173	11.53	7.75	0.86	0.53	20.70
SUBTOTAL		56310	3725.08	2352.27	282.78	172.71	6732.84
Equipment							
Milking equipment, double 4	10	19800	1752.00	950.10	108.90	65.34	2936.34
Bulk tank	10	8125	731.25	402.19	44.69	26.51	1204.94
Silo unloader, horizontal	8	2760	327.75	130.41	14.49	5.69	451.34
Manure spreader, large	8	1800	202.50	89.10	9.90	5.94	307.44
Mix mill	8	4500	540.00	237.60	26.40	15.84	819.84
Front-end loader	8	575	64.69	25.46	3.16	1.90	95.21
Scraper, rear mounted	8	330	37.13	16.33	1.81	1.09	56.36
Irrigation equipment	8	1340	150.75	66.33	7.37	4.42	228.87
Irrigation pump	6	550	82.50	27.22	3.02	1.81	114.55
SUBTOTAL		40050	3915.57	1977.74	219.74	131.81	6247.89
GRAND TOTAL OF ANNUAL OPERATING EXPENSES							$12950.73

Source: North Carolina Agricultural Extension Service Budget #10-1, prepared by R.C. Wells, G.S. Parsons and Fred Knott, 1970.

Appendix Table 2. On-farm machinery complement

NCSU budget code	Name of equipment	1983 Purchase value (dollars)	Salvage value (dollars)	Years life
2	Diesel, 40 hp tractor	12830	4237	10
5	Diesel, 50 hp tractor	25406	8375	10
17	Pickup truck	9464	3424	5
35	Chisel plow	1367	271	10
39	Tandem disc, 12 pt.	4831	957	10
45	Section harrow	597	110	10
46	Corn planter w/att.	5708	1126	10
50	Grain drill, 12 pt.	4605	904	10
70	Sprayer, tm, 110 gal.	915	181	10
83	Forage harvester, pto	10351	1811	10
84	Forage harvester, pickup att.	3070	563	10
85	Hay baler, csb*	7220	1314	10
91	Sickle mower	2787	516	10
92	Bush hog, 7 ft.	1367	252	10
94	Side delivery rake	1991	376	10
95	Mower/conditioner/windrow	8812	1614	10
96	Bale wagon	1931	385	10
98	Silage wagon, ru	6709	1220	10
100	Farm wagon	755	141	10
	Bale conveyer**			
	Forage blower***			
	SUBTOTAL	$110716.00		

NCSU budget code	Name of equipment	Annual ownership expenses (dollars): Depreciation	Interest	Insurance	Taxes	Total
2	Diesel, 40 hp tractor	859.20	1194.60	65.40	38.40	2160.60
5	Diesel, 50 hp tractor	1702.50	2364.00	135.00	76.20	4278.00
17	Pickup truck	1208.00	902.00	51.50	28.50	2190.00
35	Chisel plow	109.60	114.65	6.55	4.10	234.90
39	Tandem disc, 12 pt.	387.40	405.20	23.20	14.50	830.30
45	Section harrow	48.70	49.50	2.80	1.80	102.50
46	Corn planter w/att.	458.18	478.42	27.38	17.10	981.08
50	Grain drill, 12 pt.	370.05	385.65	22.05	13.80	791.55
70	Sprayer, tm, 110 gal.	73.45	76.70	4.36	2.73	157.24
83	Forage harvester, pto	853.95	851.40	48.65	31.05	1785.08
84	Forage harvester, pickup att.	250.73	254.33	14.55	9.22	525.83
85	Hay baler, csb*	590.63	597.38	34.12	21.62	1243.75
91	Sickle mower	227.10	231.20	13.20	8.40	479.90
92	Bush hog, 7 ft.	111.50	113.30	6.50	4.10	235.40
94	Side delivery rake	161.52	165.72	9.45	6.00	342.72
95	Mower/conditioner/windrow	719.80	729.80	41.70	24.60	1515.90
96	Bale wagon	154.68	162.12	9.24	5.76	331.80
98	Silage wagon, ru	548.88	555.00	31.68	20.16	1155.72
100	Farm wagon	61.50	62.75	3.50	2.25	130.00
	Bale conveyer**					
	Forage blower***					
	SUBTOTAL	8897.67	9693.72	553.89	330.29	
	GRAND TOTAL, ANNUAL OPERATING EXPENSES					19475.57

*CSB = Conventional Square Bales. **Budget data unavailable. ***Hay harvest unit consists of haybine, rake, two tractors, three wagons, pop-up loader, bale conveyer, electric motor, and five men.

Source: 1983 Farm Planning Guide, North Carolina Agricultural Extension Service, North Carolina State University, Raleigh.

Appendix Table 3. Agricultural Extension Service Budget 20-2: Beef Cow-Calf Operation

COW/CALF.0

Budget 20-2
1/83

BEEF COW-CALF: Estimated revenue, operating expenses, annual ownership expenses and returns to land, overhead and management on a per cow bais for 50 cows and 2 bulls on ladino-grass pasture, fescue pasture, coastal bermuda pasture and corn silage (90% calf crop).

Category	Description	Unit	Price	Quantity	Value	Your Value
Gross revenue:						
Steer calves	.45 sold (525 lbs ea)	Cwt.	$ 62.50	2.36	$147.50	
Heifer calves	.21 sold (475 lbs ea)	Cwt.	50.00	1.00	50.00	
	.24 held as replacement					
Cull cows	.14 sold (1,000 lbs ea)	Cwt.	38.00	1.4	53.20	
Cull heifers	.08 sold (750 lbs ea)	Cwt.	42.00	.6	25.20	
Cull bulls	.008 sold (1,712 lbs ea)	Cwt.	45.00	.14	6.30	
Total Revenue					$282.20	
Operating expenses:						
Ladino-grass pasture	1 acre/cow	Acre	$ 39.73	1.00	$ 39.73	
Fescue pasture	.2 acre/cow	Acre	79.43	.2	15.89	
Coastal Bermuda pasture	.2 acre/cow	Acre	98.74	.2	19.75	
Corn silage	2.8 tons/cow	Acre	173.66	.14	24.31	
Urea	26 lbs/cow	Cwt.	13.70	.28	3.84	
Salt & Minerals	30 lbs/cow	Cwt.	11.75	.30	3.53	
Vet & Medication	(with calf implant)	Hd.	11.00	1.00	11.00	
Sales comm. & transportation		Hd.	8.00	.888	7.10	
Repairs for cattle equipment (2% of initial cost)		Dol/Hd.	02%	212.20	4.24	
Interest on operating capital (9 mo)		Dol/Hd.	14%	122.29	12.84	
Total operating expenses					$142.23	
Returns over operating expenses					$139.97	
Capital Costs:						
Interest on cattle equipment & facilities					$101.65	
Interest on crops equipment & machinery & fixed establishment cost					23.59	
Total interest charge					$125.25	
Returns to land, overhead, labor, management, & machinery					$ 14.72	
Ownership cost: (depreciation, taxes, insurance)						
Cattle equipment & facilities					$ 22.13	
Crops machinery establishment					46.48	
Total ownership cost					$ 68.61	
Total cost per cow					$336.08	
Returns to land, overhead, labor[a] & management per cow					- 53.88	

Prepared by J. E. Standaert, Extension Economist with assistance from R. G. Crickenberger, Extension Animal Husbandry.

[a]Livestock labor for a 50 cow herd will range between 9 and 14 hours per cow. Crop labor will be approximately 1.6 hours per cow.

Appendix Table 4. Agricultural Extension Service
Budget 10-4: Dairy Herd Replacements

DAIRY HERD REPLACEMENTS: Estimated revenue, expenses and returns to land, overhead and management from rearing a springing heifer from birth, by periods, (large dairy breeds)[a/]

Category	Unit	Price	Birth to 6 months Quantity	Birth to 6 months Value	6 to 12 months Quantity	6 to 12 months Value	12 to 24 months Quantity	12 to 24 months Value	Birth to 24 months Quantity	Birth to 24 months Value
Gross Revenue										
Springing heifers	Head	$1100							1	$1,100.00
Cull value[d/]										24.50
Total Revenue										$1,124.50
Operating Expense										
Value of calf at birth	Head	$100.00	1	$100.00					1	$ 100.00
Milk replacer	Lb.	0.60	40	24.00					40	24.00
Calf starter	Lb.	0.11	250	27.50					250	27.50
Concentrates	Lb.	0.08	450	36.00	600	$ 48.00	400	$ 32.00	1450	116.00
Hay[b/]	Lb.	83.18	0.25	20.80	0.70	58.23	1.10	91.50	2.05	170.53
Corn silage[b/]	Tons	15.28			0.75	11.46	2.50	38.20	3.25	49.66
Pasture[b/]	Days	0.24			60	14.40	200	48.00	260	62.40
Bedding	Cwt.	2.00	2	4.00	5	10.00	5	10.00	12	24.00
Vet and medication	head			6.00		4.00		4.00		14.00
Breeding	head							20.00		20.00
Power and machinery	head			3.34		6.17		12.43		21.99
Supplies	head			3.00		2.00		2.00		7.00
Repairs	head			8.21		9.69		19.60		37.50
Mortality and culling[d/]	Percent		9	28.55		11.59	5	16.35	15	56.49
Interest on operating capital[e/]	Dol.	0.14		13.27		25.37		87.17		125.81
Total operating expense per period				$274.67		$200.91		$381.30		$ 856.88
Total accumulated operating expense				$274.67		$475.58		$856.88		$ 856.88
Returns over operating expenses										$ 267.62
Ownership expenses										
Specialized cattle facilities[f/]										$ 73.31
Cattle machinery and equipment[g/]										$ 34.50
Total ownership expenses										$ 112.81
Returns to land, overhead, labor and management										$ 154.81
Labor										
Livestock labor	Hours	$ 4.50	12	$ 54.00	8	$ 36.00		$ 45.00	30	$ 135.00
Returns to land, overhead and management[h/]										$ 19.81

Appendix Table 4 (continued)

Explanatory Notes for Dairy Herd Replacements

a) Heifer rearing programs vary widely from farm to farm. This breakdown of the 36 heifer budget is provided to facilitate adjustments for specific circumstances. Above average management is assumed, based on the management practices recommended in "A Guide to Raising Dairy Calves, leaflet AG-194, N. C. Agricultural Extension Service, and "Raising Dairy Herd Replacements" and "Management of Dairy Herd Replacements," sections G-1 and G-2, Dairy Handbook for Agricultural Workers, N. C. Agricultural Extension Service.

b) Total costs, including operating, ownership and labor expenses, see forage budgets. Forage costs vary according to weather, soil type, total acreage, machinery investment, and management. Thus forage costs are likely to be higher for smaller dairy farms and for non-dairy farms raising dairy heifers for sale or under contract. Storage and feeding losses are assumed to be 12 percent for baled hay and 18 percent for corn silage.

c) Repairs to specialized cattle facilities are 2 percent of original cost plus the heifers share of tractor, feed and manure handling equipment, etc. used jointly with the dairy herd.

d) Death losses vary widely from farm to farm but 10 percent loss is assumed here. For simplicity, 8 percent mortality is assumed shortly after birth and before significant operating costs are incurred, 1 percent at 6 months and 1 percent at 12 months. In addition, it is assumed that 5 percent of the heifers fail to breed and are sold for beef at 24 months. Mortality and culling losses require that more heifer calves enter the replacement rearing program and the lost animals add to the cost of the surviving heifers.

e) Based on the average accumulated operating expenses for each period.

f) See attached list.

g) Heifer share of tractor, feed and manure handling equipment etc. used jointly with the dairy herd.

h) Calving at 25 months instead of 24 months adds $33.02 to operating expenses and $3.75 to labor costs.

Appendix Table 5. Dairy cow budget,[a] Central Piedmont, North Carolina

Item description	Cost/head (dollars)
Bedding	10
Breeding fees	25
Veterinarian and medicine	35
Dairy supplies	60
DHIA testing	15
Machine repairs	30
Utilities	50
Tractor gas, oil, lubrication	20
Building maintenance and repairs	30
Miscellaneous expense	20
TOTAL	295

[a]No provision is made in this budget for feeding expense or replacement animal expenses.

Appendix Table 6. Orchardgrass hay budget

Category	Units		Price	Quantity	Number of times	Value (dollars)
Production:						
No. 2 hay	Tons		60.00	4.00		
TOTAL RECEIPTS						240.00
Baling and operating inputs:						
0-10-20 bulk	Cwt.		6.55	4.00	1.00	26.20
Dry fert. spread	Acre		5.50	1.00	1.00	5.50
30% nitro. solution	Cwt.		7.16	2.22	3.00	47.69
Lime, dolom. applied	Tons		26.00	0.25	1.00	6.50
Baler twine	Lbs.	(Baling)	0.66	4.26	3.00	8.43
Electricity	Kwh.	(Baling)	0.06	5.32	3.00	0.96
Tractor fuel and lubrication	Acre	(Baling)		4.91	3.00	14.73
Tractor repair cost	Acre	(Baling)		1.86	3.00	5.58
Machinery repair cost	Acre	(Baling)		3.25	3.00	9.75
TOTAL ANNUAL OPERATING EXPENSES						125.33
Establishment costs prorated over 4 years:		Prorate factor				
Orchardgrass seed	Lbs.	0.25	1.00	15.00	1.00	3.75
10-10-10, bulk	Cwt.	0.25	7.62	5.00	1.00	9.53
Lime, dolom. applied	Tons	0.25	26.00	2.00	1.00	13.00
Dry fert. spread	Acre	0.25	5.50	1.00	1.00	1.38
Tractor fuel and lubrication	Acre	0.25		4.68	1.00	1.17
Tractor repair cost	Acre	0.25		1.86	1.00	0.47
Machinery repair cost	Acre	0.25		0.79	1.00	0.20
TOTAL PRORATED ESTABLISHMENT COSTS						29.48
ANNUAL OPERATING EXPENSES + PRORATED ESTABLISHMENT EXPENSES						154.81
Labor hours:						
Fertilizer application in February						0.20
Baling per cut				2.20	3.00	6.60
Establishment		0.25		1.11		0.28
LABOR HOURS IN MATRIX COLUMN						7.08

Source: Budgets No. 86-8, 86-10 and 84-4 and communication with Agricultural Extension Service specialists.

Appendix Table 7. Fescue hay budget

Category	Units		Price	Quantity	Number of times	Value (dollars)
Production:						
No. 2 hay	Tons		60.00	4.00		
TOTAL RECEIPTS						240.00
Baling and operating inputs:						
0-10-20 bulk	Cwt.		6.55	4.00	1.00	26.20
Dry fert. spread	Acre		5.50	1.00	1.00	5.50
30% nitro. solution	Cwt.		7.16	2.22	3.00	47.69
Lime, dolom. applied	Tons		26.00	0.33	1.00	8.58
Baler twine	Lbs.	(Baling)	0.66	4.26	3.00	8.43
Electricity	Kwh.	(Baling)	0.06	5.32	3.00	0.96
Tractor fuel and lubrication	Acre	(Baling)		4.91	3.00	14.73
Tractor repair cost	Acre	(Baling)		1.86	3.00	5.58
Machinery repair cost	Acre	(Baling)		3.25	3.00	9.75
TOTAL ANNUAL OPERATING EXPENSES						127.41
Establishment costs prorated over 10 years		Prorate factor				
Orchardgrass seed	Lbs.	0.10	0.52	20.00	1.00	1.04
10-10-10, bulk	Cwt.	0.10	7.62	5.00	1.00	3.81
Lime, dolom. applied	Tons	0.10	25.00	2.00	1.00	5.00
Dry fert. spread	Acre	0.10	5.50	1.00	1.00	0.55
Tractor fuel and lubrication	Acre	0.10		4.68	1.00	0.47
Tractor repaircost	Acre	0.10		1.86	1.00	0.19
Machinery repair cost	Acre	0.10		0.79	1.00	0.08
TOTAL PRORATED ESTABLISHMENT COSTS						11.13
ANNUAL OPERATING EXPENSES + PRORATED ESTABLISHMENT EXPENSES						138.54
Labor hours:						
Fertilizer application in February						0.20
Baling per cut				2.20	3.00	6.60
Establishment		0.10		1.11		0.11
LABOR HOURS IN MATRIX COLUMN						6.91

Source: Budgets No. 86-1, 86-3 and 84-4 and communication with Agricultural Extension Service specialists.

Appendix Table 8. Prices received per hundred pounds of milk, net of deductions for hauling, marketing and promotion[a]

Net blend price	Net class I price	Net class II price
$ 17.68	$ 18.50	$ 14.43
16.68	17.50	13.43
15.68	16.50	12.43
14.68	15.50	11.43
13.68*	14.50*	10.43*
12.68	13.50	9.43
11.68	12.50	8.43
10.68	11.50	7.43
9.68	10.50	6.43
8.68	9.50	5.43

[a]Assumes $1 deduction per hundredweight of milk for these charges.

*Prices used in base plan.

Appendix Table 9. Prices received per hundred pounds of liveweight beef animal, by animal class[a]

Steer calves	Heifer calves	Cull heifers	Cull cows
	(dollars per hundred pounds)		
87	77	70	57
82	72	65	52
77	67	60	47
72*	62*	55*	42*
67	57	50	37
62	52	45	32
57	47	40	27
52	42	35	22
47	37	30	17
42	32	25	12

[a]The following animal types are assumed: Steer calf marketed at 525 pounds; heifer calf marketed at 475 pounds; cull heifer marketed at 750 pounds; cull cow marketed at 1000 pounds.

*Prices used in base plan.

Appendix Table 10. Optimal enterprise combination by hours of hired labor availability

	Unit	Hours of hired labor availability: 0	1,287	2,550	3,825	5,100	Unconstrained Case **
Variable Profit	Dollars	63,435	69,883	76,332	82,434	88,243	96,059
Variable Profit: Change from base plan	Dollars	-12,897	-6,449	BASE	+6,102	+11,911	+19,727
Enterprise levels:							
Dairy Cows	Head	56	70.6	85.2	99.8	114	133.1
Beef Cow-calf	Units	0	0	0	0	0	0
Wheat	Acres	60.1	39.3	18.5	0	0	0
Off-farm work	Hours	0	0	0	0	0	0
Owned land used:							
Pasture	Acres	50 *	50	50	50	50	50
Row-crop land used for crops	Acres	140 *	140	140	127.4	113.5	94.8
Row-crop land used for pasture	Acres	0	0	0	12.6	26.5	45.2
Rented land used:	Acres	4.8	19.1	33.4	35 *	35	35
Row-crop land used for crops	Acres	0	0	0	14.8	49	95
Row-crop land used for pasture	Acres	0	0	0	0	0	0
Dual value for additional labor	Dollars	11.56	11.56	11.56	11.06	11.06	0
Dual value for additional row-crop land	Dollars	0	0	0	0	0	0
Dual value for additional row-crop land	Dollars	0	0	0	0	0	209.84

*Indicates maximum amount of resource available.

**6815.3 hours hired - equivalent to 2.67 man-years of labor.

Appendix Table 11. Optimal enterprise combination by level of family labor supply

Item	Unit	Hours of labor provided by family		
		1,288	2,563	3,838
Variable profit	Dollars	31,983	46,860	61,596
Variable profit: change from base plan	Dollars	-44,349	-29,472	-14,736
Enterprise levels:				
Dairy cows	Head	41.5	56	70.6
Beef cow-calf	Units	0	0	0
Wheat	Acres	80.9	60.1	39.3
Off-farm work	Hours	0	0	0
Owned land used:				
Pasture	Acres	40.6	50*	5
Row cropland used for crops	Acres	140*	140	140
Row cropland used for pasture	Acres	0	0	0
Rented land used:				
Pasture	Acres	0	4.8	19.1
Row cropland used for row crops	Acres	0	0	0
Row cropland used for pasture	Acres	0	0	0
Hired labor used:	Hours	2,550*	2,550	2,550
Dual value for additional labor	Dollars	11.73	11.56	11.56

Item	Unit	Hours of labor provided by family			
		5,113	6,338	7,663	8,939
Variable profit	Dollars	76,332	90,721	104,818	118,915
Variable profit: change from base plan	Dollars	BASE	+14,389	+28,486	+42,583
Enterprise levels:					
Dairy cows	Head	85.2	99.7	114	128.2
Beef cow-calf	Units	0	0	0	0
Wheat	Acres	18.5	0	0	0
Off-farm work	Hours	0	0	0	0
Owned land used:					
Pasture	Acres	50	50	50	50
Row cropland used for crops	Acres	140	127.4	113.5	99.6
Row cropland used					

Appendix Table 11 (continued)

		Hours of labor provided by family			
Item	Unit	5,113	6,338	7,663	8,939
Owned land used:					
Pasture	Acres	50	50	50	50
Row cropland used for crops	Acres	140	127.4	113.5	99.6
Row cropland used for pasture	Acres	0	12.6	26.5	40.4
Rented land used:					
Pasture	Acres	33.4	35*	35	35
Row cropland used for row crops	Acres	0	14.8	49	83.2
Row cropland used for pasture	Acres	0	0	0	0
Hired labor used:					
Dual value for additional labor	($)	11.56	11.06	11.06	11.06

*Indicates maximum amount of resource available.

Agricultural Research Service

North Carolina State University
Raleigh, North Carolina

Ronald J. Kuhr
Director of Research