AN ANALYSIS OF LEAST COST ROUGHAGE SYSTEMS FOR DAIRY CATTLE IN THE OKLAHOMA CITY MILKSHED

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CHAPTER I

INTRODUCTION

The dairy industry in Oklahoma, as most segments of the state's agricultural industry, is experiencing a rapid increase in the use of highly mechanized techniques and equipment. Accompanied by increases in milk production per cow and managerial ability, this change has enabled the dairyman to produce larger volumes of milk.

Like most technological changes, this dynamic development in the young dairy industry in Oklahoma is shadowed by problems of readjustment. Aggregate supply and demand relations between production and consumption within the state of Oklahoma indicate that there is essentially a balance between production and consumption.[1] This condition, coupled with the inelastic demand for dairy products, indicates that, in the aggregate, the present task confronting the Oklahoma dairy industry is not to increase production but to increase the efficiency of production.

The individual dairyman in Oklahoma is concerned with profit maximization. The basis for determining the maximum profit from an Oklahoma dairy enterprise is a micro-static economic analysis of the individual

[1]Herbert W. Grubb, "A Linear Program Analysis of Grade A Dairy Farm Organizations in the Oklahoma Metropolitan Milk Marketing Area" (unpublished Master of Science thesis, Oklahoma State University, 1960), p. 3.

farm. Such an analysis in its entirety is beyond the scope of this study. Rather, the study assumes a fixed dairy plant with a fixed output and seeks to minimize feed costs. Results from this study can help the individual dairymen reduce costs and can help the state dairy industry increase production efficiency.

Statement of the Dairyman's Problem

The cost minimizing task confronting the dairyman is one of examining the present farm organization and determining how the present output can be produced more efficiently. Grubb found that on-farm production of roughages contributed most to minimizing costs of Oklahoma dairymen.[2] Previous research indicated many sources of roughages in use by dairymen could be replaced with more efficient sources. The portion of the dairyman's task dealt with by this study is determining the optimum roughage system under given production situations.

Objective and Procedure Used in the Study

The objective of this study is to determine the least cost combination of roughages for dairy cattle, given restrictions on nutrient requirements and stomach capacity of the dairy animals for roughage and grain.

Cost and yield coefficients were obtained on the types of roughage available in the Oklahoma City milkshed, the area chosen for the study.[3]

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[2]Ibid., p. 108.

[3]For a detailed description of the dairy farms in the two counties on which this study is based, see F. J. Smith, "A Linear Program Analysis of Roughage Systems for Grade A Dairy Farms in Grady and Lincoln Counties" (unpublished Master of Science thesis, Oklahoma State University, 1962).

Requirements of typical dairy cows were computed for two efficiency levels of production; also, the growth and maintenance requirements of heifers kept for herd replacements were computed. The needs of livestock for nutrients were related to the cost and yield data for roughages by a linear programing model in which costs of producing roughages were minimized for given animal needs. Solutions for different production situations were then interpreted as to their usefulness to the dairyman in his management of the dairy herd.

Previous Research in Oklahoma

Considerable research has been completed on the analysis of the dairy industry in Oklahoma. Underwood conducted an economic survey of resources used by dairy farmers in Oklahoma which has helped further micro-economic analyses of individual dairy farms.[4]

Grubb conducted a study dealing with the farm organization in its entirety. He accepted common roughage programs without analyzing their relationship to the least cost system.[5] However, Grubb did conclude that on-farm production of roughages contributed most to total profits.

Smith found that dairymen could save at least $10 per cow by a reorganization of their roughage systems.[6] Smith also concluded that while 60 sources of roughages were in use by dairymen in Grady and

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[4]F. L. Underwood, Economic Survey of Resources Used by Dairy Farmers in Oklahoma, Agricultural Experiment Station Bulletin No. B-482 (Oklahoma State University, December, 1956).

[5]Grubb.

[6]F. J. Smith.

Lincoln counties of Oklahoma, only 12 actually appeared in least cost program results, indicating many roughages are relatively inefficient and could be eliminated from the systems. However, there may have been reasons for some of the apparently inefficient roughages being in use which Smith did not consider. For example, Smith failed to consider the distribution of digestible protein over the seasons and the limiting stomach capacity of the dairy cows. Most of the input-output data used in the present study is based on the survey conducted by Smith.

Smith estimated cost and yield coefficients and derived least cost roughage combinations for providing total digestible nutrients. However, he used only total digestible nutrients as a basis for the nutrient requirements of the dairy animal. Smith's solutions usually provided an adequate amount of digestible protein in the aggregate for the year. However, there were specific months during the year when the least cost roughage system was not providing the dairy animal with the digestible protein required. Another restriction not analyzed by Smith was stomach capacity. Although his study determined least cost methods of producing the required total digestible nutrients, there was no assurance the animal could consume the quantity of nutrients and convert it to milk. Thus, there existed a need to assure that required nutrients and energy would be distributed over the production cycle according to the level of production.

Sparks presented feeding systems for replacement heifers in a recent study at Oklahoma State University.[7] He used the budgeting technique

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[7]Donald E. Sparks, "An Analysis of Dairy Herd Replacements in Grady and Lincoln Counties" (unpublished Master of Science report, Oklahoma State University, 1962).

and did not look at as many alternatives as could be examined using the linear programing method.

The problem of determining more efficient roughage systems for Oklahoma dairymen and the shortcomings of previous research on the problem have prompted the present study.

CHAPTER II

ANALYTICAL PROCEDURE

Many commonly occurring problems of maximizing or minimizing functions are dealt with by agricultural economists. Profits and utility are maximized while hours of labor, machine time, and, in the present case, costs are minimized. The tools of the trade for handling these problems are varied. Methods considered for this study were budgeting, functional analysis, and linear programing.

If there were but a few combinations of roughages and grain which satisfy the requirements of the dairy animal, budgeting could be used to determine a feasible solution that was reasonably "in line" as to total cost.

Functional analysis would be useful if the number of nutrient sources were small enough to prevent the technique from becoming too cumbersome and it were known beforehand which inputs would appear in the solution at positive levels. In this linear programing study of roughage programs, more sources of roughages were analyzed than appeared in the solution, and the number of sources studied was so great that functional analysis would have been too cumbersome. Functional analysis is good for studying imperfect substitution among nutrient sources, whereas, for the linear programing approach used in this study, a pound of TDN or DP from a specific source was assumed equal to a pound from any other source, thus perfect substitution.

The present analysis of least cost roughage systems was cast in the framework of linear programing. The amounts of nutrients in the feed mixture are assumed to be linear functions of the quantities of different roughages and grains.[8] Linear programing presents some difficulties not encountered by budgeting and functional analysis. However, linear programing does alleviate the difficulties encountered in the two alternative techniques discussed and was the method employed by the study.

The Linear Programing Model

Linear programing is a technique for obtaining a unique value-weighted solution to a set of simultaneous linear equations in which the number of unknowns may exceed the number of equations and in which no variate has a negative value.[9] This definition means that the linear programing technique maximizes (minimizes) a criterion function subject to linear restraints. More variables may be analyzed than appear in the solution, and all inputs are positive or zero.[10]

Objective Function and Restrictions

The criterion function for which the unique-value weighted solution (least value in the present case) will be found is the total cost of the

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[8]F. V. Waugh, "The Minimum-Cost Dairy Feed", Journal of Farm Economics, XXXIII, August, 1951, p. 300.

[9]R. H. McAlexander and R. T. Hutton, Linear Programing Techniques Applied to Agricultural Problems, A. E. and R. S. #18, Agricultural Experiment Station, The Pennsylvania State University, University Park, Pennsylvania, p. 4.

[10]For a complete discussion of linear programing, see E. O. Heady and Wilfred Candler, Linear Programming Methods (Iowa, 1958).

roughage program.[11]

$$(1) \quad TC = \sum_{j=1}^{n} C_j X_j$$

where C_j is the unit cost and X_j is the quantity of the j^{th} roughage. The following restrictions are imposed on the total cost equation which insure that the required nutrients are provided:

$$(2) \quad TDN_i \leq \sum_{j=1}^{n} A_{ij} X_j$$

$$(3) \quad DP_i \leq \sum_{j=1}^{n} B_{ij} X_j$$

$$(4) \quad DM_i \geq \sum_{j=1}^{n} D_{ij} X_j$$

$$(5) \quad X_j \geq 0$$

$$j = 1, 2, \ldots n$$

$$i = 1, 2, \ldots, 12$$

Inequality (2) states that the quantity of total digestible nutrients (TDN) provided (A_{ij}) by the various roughages (X_j) is greater than or equal to the quantity required (TDN_i) in the i^{th} month. The number of roughages runs from 1 to n and the months run from 1 to 12. In the actual computations, the equality signs were made to hold.

Inequality (3) provides that the digestible protein (DP) provided (B_{ij}) by the various roughages (X_j) in the i^{th} month is greater than or equal to the quantity required in the i^{th} month (DP_i).

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[11]Throughout the content of the study, reference will be made to the terms "roughages" or "roughage program". However, the reader should keep in mind that a mixed grain is also included in the analysis.

Stomach capacity is a question of volume. The volume of roughage and grain an animal can consume in any one day is relatively constant throughout the year. The energy required by the animal for milk production, however, varies over the year as the stages of lactation progress. The problem is one of insuring that the changing nutrient requirements demanded by the dairy cow at varying levels of milk production are provided by a volume of feed mixture which the animal can consume. Dry matter is closely correlated with volume. Dry matter content of roughages is readily accessible; therefore, the study analyzes the stomach capacity restriction on a dry matter basis. Inequality (4) states that the nutrients required by inequalities (2) and (3) do not constitute a larger quantity of dry matter than the animal can consume.

Inequality (5) prevents any roughage from entering the program at a negative level. This restriction is provided for in the Perry and Bonner program used, and it was not necessary to include inequalities of this type in the linear programing model.[12]

To illustrate the model, assume a dairy cow in June requires 600 pounds of TDN, 100 pounds of DP, and can consume up to 900 pounds of dry matter during the month. Assume further that two sources of nutrients are available. Roughage A provides 200 pounds of TDN, 100 pounds of DP, and 360 pounds of dry matter per acre in June. Roughage B provides 400 pounds of TDN, 10 pounds of DP, and 420 pounds of dry matter in the month of June. Both roughages A and B cost $10 per acre.

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[12]O. R. Perry and J. S. Bonner, Linear Programing Code for the Augmented 650, 650 Program Library File Number 10.1.006, Western Region International Business Machines Corporation.

From the above hypothetical data, a criterion function and three restrictive inequalities can be written:

$$(6) \quad TC = 10\ A + 10\ B$$

$$(7) \quad 600 \leq 200\ A + 400\ B$$

$$(8) \quad 100 \leq 100\ A + 10\ B$$

$$(9) \quad 900 \geq 360\ A + 420\ B$$

Equitation (6) and inequalities (7), (8), and (9) can be converted to acre values, solved for roughage A, and plotted on a factor-factor map. Equation (6) gives

$$(10) \quad A = .1\ TC - B.$$

This equation represents an iso-cost line. Any number of iso-cost lines can be plotted in Figure 1, each representing a given total cost.

Inequality (7) results in

$$(11) \quad A \geq 3 - 2\ B.$$

This inequality, with the equality holding, plotted in Figure 1 is a minimum iso-TDN line that satisfies the June requirements.

Inequality (8) results in

$$(12) \quad A \geq 1 - .1\ B.$$

Inequality (12), with the equality holding, is the minimum iso-DP line that satisfies the animal's June requirement when plotted in Figure 1.

In a similar manner, inequality (9), with the equality holding, yields a maximum iso-DM line which sets an upper limit on the quantity of dry matter the animal can consume in one month when plotted in Figure 1.

$$(13) \quad A \leq 2.5 - 7/6\ B$$

Figure 1 indicates the least cost combination of roughage A and B satisfying the animal's nutrient requirements for June must lie in the triangle CDE. The iso-TDN and iso-DP lines put lower bounds on the area

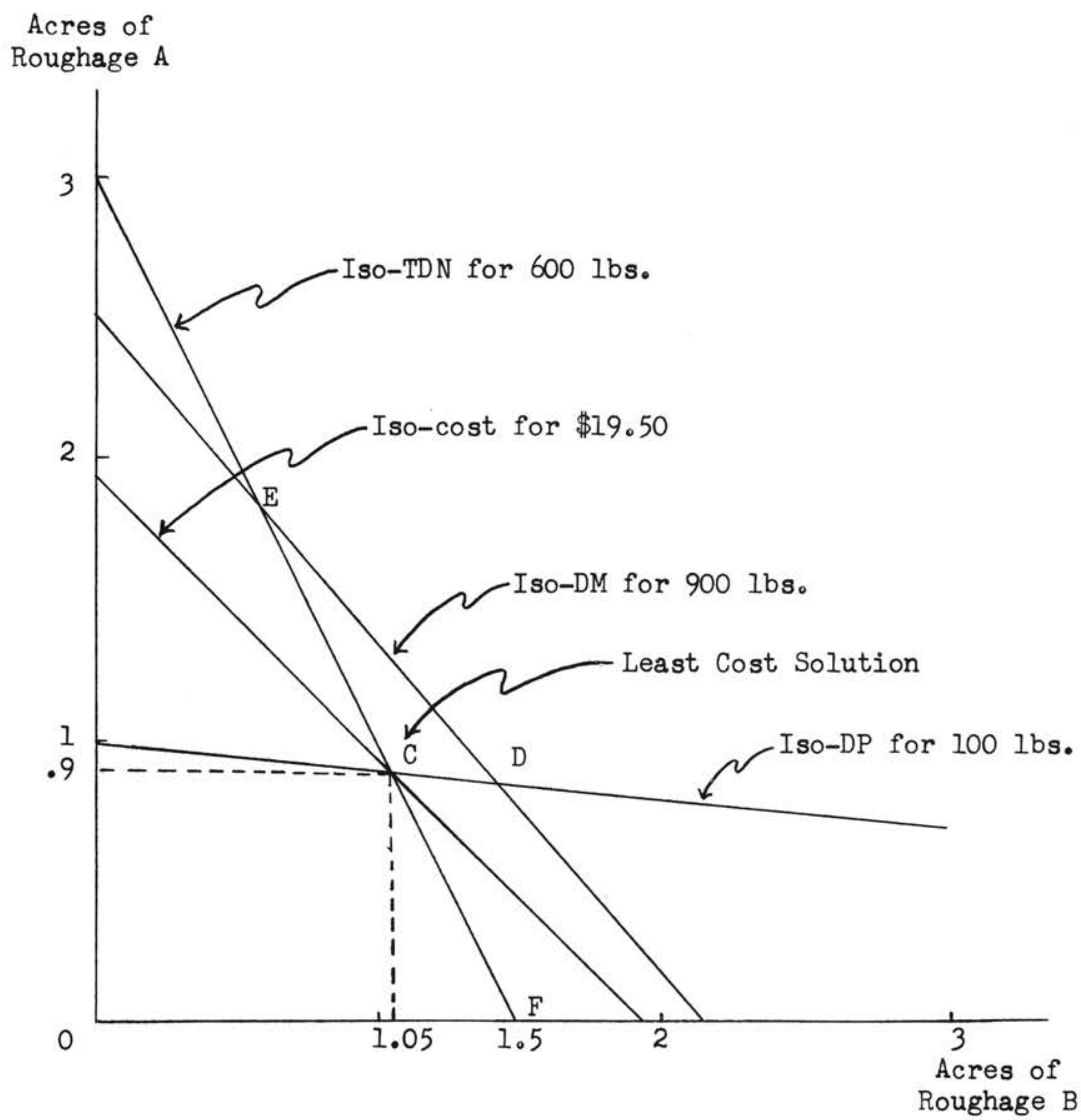

Figure 1. Sample Linear Programing Model

of feasible solutions while the iso-DM line represents the maximum quantity of feed the given animal can consume in one month, thus forming the upper boundary. The iso-cost line representing the least cost combination of roughages A and B that can satisfy the requirements (contained in triangle CDE) is the $19.50 iso-cost line. Thus, the least cost solution is represented by point C. It requires .9 acres of roughage A, 1.05 acres of roughage B, and costs $19.50.

If the digestible protein requirement were not considered, the least cost method of providing the nutrients required by the animal in June would be represented by point F. This solution would contain 1.5 acres of roughage B and would cost $15.00.

Inequalities of type (2) were held as equalities in the programing of the study. This requires the solution to lie on the iso-TDN line. The DP restrictions imposed require the solution to be on or above the iso-DP line, while the stomach capacity prevents the solution from occurring above the iso-DM line. Thus, the restraints imposed by the model require the solution to lie on the line segment CE. Since the iso-cost curve is linear, the least cost combination will be at point C as in the example or at point E, depending on the price ratio of the roughages. The price ratio is represented by the slope of the iso-cost line. When the iso-cost line has less slope than the iso-TDN line, the solution will be at point C. When the iso-cost line has greater slope than the iso-TDN line, the solution will occur at point E.

For the complete model there would be 12 inequalities of each of the three types TDN, DP, and DM; one for each of the 12 months for a total of 36 restrictions. In Chapter IV, 182 processes are considered; this would indicate a 36 x 182 matrix. Analyzing a program with a matrix of this size would require 6,992 storage spaces on the IBM 650 computer when the Perry and Bonner Linear Programing Code is used. The IBM 650 computer has a storage capacity of only 1,900 spaces. To stay within the storage capacity of the computer, a trial program of each model of a specific type of dairy animal considered was run with several activities deleted. The trial program indicated that in some months the digestible protein and stomach capacity requirements would not be limiting and could be omitted to save space. Also, many processes were so much less efficient than the majority of processes that they were analyzed only on a spot check basis to save space.

Computational Format

Table I represents the computational format for preparing the input-output data for programing on the augmented 650 electronic computer using the Perry and Bonner programing code.[13] Coefficients of the example presented in Figure 1 are used in this table.

Each row in Table I represents the restriction corresponding to inequalities (2), (3), and (4) respectively. The C_js represent costs.[14] The -100 C_j values on row one and two are prices on "slacks" built into the program which would allow the program not to provide the requirements. The $100 per pound penalty for falling short of the TDN or DP requirement, however, forces the program to meet the requirements because the structural processes provide sources of TDN and DP cheaper than $100

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[13]Ibid.

[14]The Perry and Bonner program is designed to maximize functions. To minimize the cost function we attach minus signs to the costs and maximize a negative function.

TABLE I

COMPUTATIONAL FORMAT FOR SAMPLE LINEAR PROGRAMING MODEL

	C_j →		-10	-10	0
	↓		Structural Processes		Disposal Process
Row		P_o	P_1	P_2	P_3
01	-100	600	200	400	0
02	-100	100	100	10	-1
03	0	900	360	420	0

per pound. No penalty is placed on the program for not using up all of the stomach capacity of the animal; thus, the C_j for row three is zero.

The P_o column contains the requirements while the structural processes P_1 and P_2 are the two sources of roughages. The prices per acre of the structural processes are the C_j values above the respective process and correspond to the C_j in equation (1). Process P_3 is a disposal or "slack" process which permits overproduction of digestible protein at no charge; therefore, the C_j value for process P_3 is zero.

CHAPTER III

DEVELOPMENT OF INPUT-OUTPUT DATA

The input-output coefficients used in the study are presented in Chapter III. They are the monthly nutrient requirements of two classes of dairy cows and their heifer calves to be kept for herd replacements; monthly and annual yields of sources of roughage analyzed by the study; and per acre costs of the programed roughages.

No land restrictions were placed on the programed solutions. However, roughage systems were derived for March and September freshening when no Class 1 land was available to the farm.[15]

The linear programing analysis utilizes the input-output coefficients in a framework of a perfectly elastic supply of roughages and a perfectly inelastic demand for roughages in the aggregate. The yields of roughages in terms of digestible nutrients are continuous at the determined prices, and the animal requirements for digestible nutrients are fixed in any one 30.5 day feeding period.[16]

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[15]Land classification by the study refers to use and does not necessarily correspond to land designation used by the Soil Conservation Service for land classification. Class 1 land is that land suitable for alfalfa; Class 3 land is suitable only for native pasture or hay; and Class 2 land is suitable for all other roughages analyzed.

[16]For the purpose of the study, the 365 days of the year were divided into 12 feeding periods of 30.5 days each, approximating the 12 months of the year.

Nutrient Requirements of Dairy Livestock

Two classes of dairy cows and one class of heifer replacements were considered by the study. One class of cows was 1,300 pound Holsteins producing 8,000 pounds of 4.0 per cent milk (FCM) per year at 24.7 per cent efficiency.[17] The second class of cows was 1,300 pound Holstein cows producing 11,000 pounds of 4.0 per cent FCM per year at 29.4 per cent efficiency. The 24.7 per cent efficient cows represent about the lowest producing cows a dairyman would likely keep in the herd, while the 29.4 per cent efficient cows represent cows of about average production.

The method used by the study to estimate the efficiency of the dairy cows is a method presented by V. R. Smith.[18] It considers the percentage of the TDN consumed that are converted into fat-corrected-milk (FCM). The equation for efficiency, more commonly termed dairy merit, is as follows:

$$\text{Efficiency} = \frac{\text{Milk energy production}}{\text{TDN energy consumption}} = \frac{340 \text{ (pounds of FCM produced)}}{1{,}814 \text{ (pounds TDN consumed)}}$$

This equation assumes that one pound of FCM has an energy equivalent of 340 calories, and one pound of TDN has an energy equivalent of 1,814 calories. The efficiency ratings are presented in Table II.

Total Digestible Nutrients

An energy standard was adopted which graduated the total digestible nutrients (TDN) allowances for milk production in terms of milk output

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[17] Fat-Corrected-Milk (FCM) equals 0.4 times the milk plus 15 times the fat. (Milk and fat are in units of actual yield.)

[18] V. R. Smith, Physiology of Lactation (Ames, Iowa, 1959), p. 183.

TABLE II

ESTIMATING PER CENT EFFICIENCY OF MILK PRODUCTION FROM BODY WEIGHT OF COW AND FOUR PER CENT FAT-CORRECTED-MILK[19]

4% Milk, Pounds Per Year (FCM)	Body Weight-Pounds 1100	1300	1500	4% Milk, Pounds Per Day
7,000	24.6	22.9	21.4	19.2
8,000	26.6	24.7	23.2	21.9
9,000	28.3	26.4	24.9	24.7
10,000	30.0	28.1	26.4	27.4
11,000	31.5	29.4	27.9	30.1
12,000	32.8	30.9	29.2	32.9
13,000	33.9	32.0	30.6	35.6
14,000	35.0	34.1	33.2	38.4

per day. Requirements from this standard are added to Morrison's maintenance requirements of 9.6 pounds per day for a 1,300 pound cow.[20] This standard is presented in Table III. The increasing average TDN requirement means the average cost curve is rising, indicating Stage II of production, i.e., diminishing returns.

The cow producing 8,000 pounds of milk per year enters lactation at 35 pounds of milk per day, holds this production for two months, and then tapers off to 15 pounds per day at the end of a 305 day lactation. Both cows are dry for a two-month period.

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[19] Ibid., p. 185.

[20] F. B. Morrison, Feeds and Feeding (Ithaca, New York, 1951), p. 1087.

TABLE III

REQUIREMENTS ABOVE MAINTENANCE FOR THE PRODUCTION OF ONE POUND OF FOUR PER CENT FAT-CORRECTED-MILK[21]

4% Milk Pounds Per Day		TDN Requirement Per Pound Milk Per Day
From	To	
0	10	.30
11	20	.31
21	30	.32
31	40	.33
41	50	.35
51	60	.37
61	70	.40
71	80	.43
81	90	.47
91	100	.53

A third class of cows weighing 1,300 pounds and producing 14,000 pounds of four per cent FCM at 33.2 per cent efficiency was initially considered. These high producing cows would come into lactation at 70 pounds of milk per day, hold this production for two months, and then taper off to 15 pounds of milk per day over the 305 day lactation. The stomach capacity restriction prohibited the cows from consuming enough of the roughages analyzed by the study to provide the required nutrients for such a high level of production. A special program containing high

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[21]J. T. Reid, "Problems of Feed Evaluation Related to Feeding of Dairy Cows", Journal of Dairy Sciences, November, 1961, p. 2131.

quality, concentrated feeds would be required to analyze these highly efficient dairy cows. Such an analysis was not conducted. Roughages analyzed by the study were of an average quality. For example, all analysis alfalfa was used with 50.7 per cent TDN. Pre-bloom alfalfa hay contains 53 per cent TDN while post-bloom alfalfa contains 47 per cent TDN. The alert dairyman could feed pre-bloom alfalfa during the early part of lactation and post-bloom alfalfa during the later stages of lactation. Roughages such as peanut hay, which contains 71.6 per cent TDN, could be fed the high producing cows. Such feeding practices pack more energy into the limited stomach capacity of the dairy cow. Dairy cows are also likely to be enticed to eat more of higher quality roughages and actually stretch their stomach capacity, gaining more energy to convert to milk.

A feeding plan presented by J. T. Reid suggests some feeding methods which would more efficiently utilize the limited stomach capacity of the high quality cow and even expand it to a limited degree. Reid suggests concentrate feeding during the dry period, reaching a level of 15 to 18 pounds by the time of calving. After calving, increasing the level of concentrates as rapidly as possible to either maximum appetite or maximum milk yield (whichever comes first) is recommended which permits the cow to determine her own level of intake. After the peak has been reached, the level of concentrates should be reduced to the lowest level which does not reduce the milk yield. In this way, feed intake tends to lead the milk yield rather than the reverse.[22]

Monthly TDN requirements for the two classes of dairy cows analyzed are presented in Table IV. The 24.7 per cent efficient cow requires a

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[22]Ibid., p. 2130.

TABLE IV

MONTHLY TDN AND DP REQUIREMENTS FOR THE DAIRY COWS CONSIDERED BY THE STUDY

Month Beginning With Freshening	Description of Animal: 1300# Cow Producing 8,000 lb. Milk Per Year		1300# Cow Producing 11,000 lb. Milk Per Year	
	TDN	DP	TDN	DP
1	671	80	915	119
2	671	80	915	119
3	641	75	854	109
4	610	71	793	100
5	580	66	732	91
6	549	62	671	81
7	519	57	610	72
8	488	52	549	62
9	488	52	488	53
10	488	50	488	50
11	488	43	488	43
12	580	52	732	68
Total	6773	740	8235	967

total of 6,773 pounds of TDN per year while the 29.4 per cent efficient cow requires 8,235 pounds of TDN per year.

Most dairymen feed some amount of grain throughout the lactation period. The study assumes that a minimum of five pounds of 14 per cent dairy feed would be fed daily except during the first of the two dry months. The TDN provided are subtracted from the monthly requirements listed in Table IV to obtain the requirements (P_o values) to enter in the programing model. Additional grain may be provided by the program. Appendix Tables A-I and A-II contain TDN P_o values, net of the five pounds of grain, for each month of the year for cows calving in each of the 12 months.

Digestible Protein

Monthly digestible protein (DP) requirements were computed corresponding to the monthly TDN requirements for the two classes of dairy cows analyzed by the study. The 24.7 per cent efficient cow requires a yearly total of 740 pounds of DP, and the 29.4 per cent efficient cow requires a total of 967 pounds of DP for the year. The DP requirements are presented by months in Table IV.

Appendix Tables A-III and A-IV contain DP requirements (P_o values) for each month of the year for dairy cows calving during each of the 12 months of the year. The quantity of DP provided by the daily feeding of five pounds of dairy feed has been subtracted from the monthly requirements to obtain the values in Appendix Tables A-III and A-IV.

Stomach Capacity

A rough estimate of the daily stomach capacity of a dairy cow is to say that it is equivalent to a 55 gallon drum. Dry matter, being closely associated with volume, is used by the study to measure the roughage consuming capacity of the dairy animals. Estimates of the stomach capacity of the two dairy cows analyzed are 34 pounds of dry matter per day for the 24.7 per cent efficient cow and 40 pounds per day for the 29.4 per cent efficient cow.

For the monthly feeding period (30.5 days) considered in the study, the 24.7 per cent efficient cow is limited to 1,037 pounds of dry matter, and the 29.4 per cent efficient dairy cow's stomach capacity is 1,220 pounds of dry matter.

To obtain the dry matter restrictions (P_0 values) for the programing model, the dry matter contained in the daily feeding of five pounds of dairy feed is subtracted from the dry matter capacity of the dairy cows. The resulting P_0 values are 910 and 1,083 for the 24.7 and 29.4 per cent efficient dairy cows respectively for the 11 feeding periods where grain feeding has been deducted.

Replacement Heifer Requirements

The feed cost for heifer replacements is programed for the period four to twenty-four months of age. The feed requirements for the first four months include milk, milk replacer, growth ration, and 280 pounds of alfalfa hay. The feed program for the first four months was considered to be constant and was not analyzed by the study.

Monthly TDN and DP requirements for replacement heifers were adopted from a study by Edwards and Sparks.[23] They were developed from Morrison's

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[23]Clark Edwards and Donald E. Sparks, Oklahoma State University Experiment Station Processed Series in process, Stillwater, Oklahoma.

requirements of TDN and DP for growth.[24] Standards for growth were based on Beltsville growth standards for Holstein cattle.[25]

The monthly TDN and DP requirements for the replacement heifers are presented in Table V. Monthly TDN and DP requirements (P_o values) for the programing model are represented by columns (7) and (8) of Table V. These P_o values are tabulated in Appendix Tables A-V and A-VI for heifers born in each of the 12 months.

Replacement heifers can obtain the required nutrients from the roughages available without reaching the limit of their stomach capacity to consume dry matter. Therefore, the dry matter restrictions were not required for the replacement heifer programs.

Yield Coefficients

Basic yield coefficients for roughages analyzed by the study were adopted from the previously discussed study by F. J. Smith. Computation of DP and dry matter coefficients were based on the TDN coefficients developed by Smith.

Total Digestible Nutrients

Annual TDN yields of roughages used in the study are presented in Table VI. For hay, silage, and dry grass processes in the program models, the annual yields are used for TDN coefficients. For pasture processes, the monthly yields of pastures expressed in TDN terms, are

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[24]Morrison, p. 1088.

[25]C. A. Matthews and M. H. Fohrman, Beltsville Growth Standards for Holstein Cattle, Technical Bulletin No. 1099, U. S. Department of Agriculture, Washington, D. C., September, 1954, p. 10.

TABLE V

MONTHLY TDN AND DP REQUIREMENTS FOR DAIRY REPLACEMENT HEIFERS[a]

Column							
(1) Month From Birth	(2) TDN	(3) DP	(4) Month From Birth	(5) TDN	(6) DP	(7) Σ Column 2 and 5	(8) Σ Column 3 and 6
1	-	-	13	305	30	305	30
2	-	-	14	314	30	314	30
3	-	-	15	320	30	320	30
4	-	-	16	326	30	326	30
5	180	25	17	332	31	512	56
6	200	26	18	338	31	538	57
7	217	27	19	344	31	561	58
8	234	28	20	349	31	583	59
9	251	29	21	354	32	605	61
10	268	29	22	359	32	627	61
11	282	29	23	364	32	646	61
12	294	30	24	369	32	663	62

[a]Columns (7) and (8) are used as P_o values in the programing models. These values are tabulated for heifers born in each of the 12 months of the year in Appendix Tables V and VI.

TABLE VI

ESTIMATED ANNUAL PER ACRE YIELDS AND COSTS FOR SOURCES OF ROUGHAGES USED IN THE STUDY, OKLAHOMA CITY MILKSHED

Type of Roughage	Yield				Total Cost[a]
	Pounds Per Acre				
	TDN[a]	DP	Dry Matter	Tons Per Acre	
Hay					
Alfalfa	3513	755	6271	3.5	$51.03
Bermuda	3788	317	7756	4.4	50.79
Bermuda-Hop Clover	2869	260	4950	3.1	43.28
Cowpea	1235	296	2172	1.3	29.34
Johnson Grass	1283	206	2301	1.3	25.79
Millet	2101	202	3681	2.0	32.80
Native	1732	173	3506	1.7	26.20
Rye Grass	1128	101	1891	1.3	22.75
Rye-Vetch	2372	741	3809	2.3	39.49
Sudan	2355	208	4332	2.4	36.47
Pasture					
Alfalfa	1830	433	3017		14.66
Barley	1754	547	3806		20.27
Bermuda	1424	190	2372		9.04
Bermuda-Lespedeza	1203	206	2060		12.02
Cowpea	872	178	1316		17.72
Johnson Grass	1492	239	2391		6.53
Millet	812	78	1125		10.62
Native	684	75	1140		5.88
Oat	1094	285	1677		17.62
Oats-Vetch	870	241	1470		19.14
Rye Grass	1830	194	2705		9.00
Rye-Vetch	1408	454	2406		19.29
Sudan	2355	198	3557		11.17
Vetch-Oats-Wheat	678	211	1116		20.67
Wheat	766	217	1194		20.42
Dry Grass					
Bermuda	1424	10	4344		9.04
Native	684	3	1491		5.88
Silage					
Grain Sorghum	3200	101	5347	9.2	75.90

[a]Source: F. J. Smith, "A Linear Program Analysis of Roughage Systems for Grade A Dairy Farms in Grady and Lincoln Counties" (unpublished Master of Science thesis, Oklahoma State University, 1962), p. 28. For monthly distribution of yields, see Appendix Tables A-VIII, A-IX, and A-X.

used for program coefficients. These monthly yields are tabulated in Appendix Table A-VIII.

Digestible Protein

Digestible protein yields of roughages used in the study are based on the TDN yields of the roughages. The DP yields were estimated using Morrison's nutrient content of feedstuffs. A conversion factor was computed which represented the ratio of DP to TDN. The TDN yield of roughages was multiplied by the conversion factor to obtain the DP yield. Digestible nutrient content and DP conversion factors for roughages analyzed are presented in Appendix Table A-VII.

Annual DP yields of roughages analyzed are presented in Table VI, and monthly DP yields of pasture crops are tabulated in Appendix Table A-IX. For hay, silage, and dry grass processes the annual yields are used for program coefficients while the monthly yields are used for pasture process coefficients.

Dry Matter

Total digestible nutrient yields were used to estimate dry matter yields of roughages analyzed by the study. TDN yields were multiplied by dry matter conversion factors from Appendix Table A-VII to obtain dry matter coefficients. For hay, silage, and dry grass processes, the annual dry matter yields from Table VI are used for program coefficients. Pasture process coefficients are obtained from the monthly dry matter yields tabulated in Appendix Table A-X.

Cost Coefficients

Per acre costs of roughages used in the study were those computed by F. J. Smith. They are based on costs of capital, establishment, harvesting, and maintenance.[26] The per acre costs are tabulated in Table VI.

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[26]For a more detailed analysis of the roughage costs, see F.J. Smith, pp. 21-23.

CHAPTER IV

PROGRAMED SOLUTIONS

This chapter presents the results of 54 linear programs analyzing the means of providing required nutrients for the three classes of dairy animals discussed in Chapter III. Of the 54 programs, referred to as cases by the study, 24 roughage systems were concerned with the low producing dairy cows, 18 with the average producing cows, and 12 with raising dairy replacement heifers.

The 24 nutrient sources included in the analysis of the 54 cases were expanded to 158 processes for obtaining digestible nutrients in specific monthly feeding periods from roughages, 12 processes for obtaining digestible nutrients from a concentrate, and 12 processes permitting production of excess digestible protein. These 182 processes represent 24 of the 61 sources of roughage and one concentrate in use by dairymen of the Oklahoma City milkshed. The 61 nutrient sources used by dairymen were discussed in Chapter III and are tabulated in Appendix Table A-XIII. This table includes a designation of the 24 sources analyzed, and the specific class of livestock for which each source was included in the analysis.

Programed solutions for the three classes of dairy animals were synthesized into a program for a hypothetical dairy herd. This dairy herd consisted of a combination of the two classes of dairy cows freshening in the spring and fall and an appropriate number of dairy replacement heifers. The roughage system for the dairy herd was constructed by summing the roughage systems for the individual segments of the herd. This system is presented at the end of the chapter.

Optimum solutions for each of the three classes of animals were programed for freshening in each of the 12 months. Near optimum solutions were also examined for spring and fall freshening by denying the use of certain unstable processes. An unstable process results when a small change (less than $1 per unit) in the cost of the process would induce a new solution.

Near optimum solutions for months other than March and September were not derived. However, near solution "activities" that could replace the unstable activities with a small increase in cost were indicated by the programed results and are presented in this chapter. The key to these "near solution" activities is the ZJ - CJ value which indicates the addition to cost which would result from the entry of one unit of the activity into the solution (also termed shadow price). The range over which the ZJ - CJ value applies defines the limits of linearity. Thus, if an upper limit of a range turns out to be 12, the variable in question can replace portions of one or many other processes in the final solution at a cost penalty per unit indicated by the ZJ - CJ value up to a limit of 12 units.[27] The ZJ - CJ would take on a higher value beyond this range.

All activities with low ZJ - CJ values are presented in Appendix Table A-XVI. Even if the activity is not a "near solution" activity in

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[27]Perry and Bonner, p. 8.

the sense that it would replace unstable activities in the solution, a dairyman might have some specific reason for wanting a certain activity in the roughage system. For example, his costs for a certain roughage may be below average. The ZJ - CJ value indicates the penalty that is paid per unit of the activity brought into the roughage system at average unit costs and yields.

Land utilization by the programed solutions is analyzed in terms of Class 1, Class 2, Class 3, and total land. Land use is presented both tabularly and graphically.

The programed solutions provide a roughage system which satisfies the monthly TDN and DP requirements of the dairy animal without exceeding the quantity of dry matter that can be consumed. Nutrients from pasture crops are consumed in the month they are produced with the exception of dry grass processes. Dry grass processes hold bermuda or native grass and pasture it during the non-growing season months. Roughage from hay processes may be consumed throughout the 12 months.

The present chapter presents solutions in both tabular and graphical form for each case considered. Chapter V will be concerned with the interpretation of the solutions and their applications for dairymen in the Oklahoma City milkshed.

Results for 1,300 Pound Dairy Cows Producing 8,000 Pounds Milk Per Year

Twenty-two roughage systems were derived which provide the required nutrients for low producing dairy cows freshening in different months of the year.

Optimum solutions were derived for groups of 100 low producing cows freshening in each of the 12 months. Near optimum solutions were programed for March and September freshening by denying unstable activities. Roughage systems were also derived for March and September freshening when no Class 1 land was available to the farm. Included in the analysis were 87 processes representing 12 pasture, 4 hay, and 2 dry grass activities. These processes and activities are identified in Appendix Table A-XIII.

Optimal Solutions for Freshening in Each of the Twelve Months

The study considered 12 groups of 100 cows, each freshening in successive months. Each group was permitted to utilize any roughage analyzed by the study for this class of livestock.[28] Results of these programs are presented in Table VII. These programs represent cases 1 01 01 through 1 01 12.[29]

Table VII offers the following generalities. Alfalfa pasture, alfalfa hay, bermuda hay, and dry bermuda grass appeared in solutions for cows freshening in every month of the year. Alfalfa was the predominant source of pasture and hay for the programed solutions. Dry native grass was utilized by cows freshening in April and June. Oats pasture was utilized by cows calving in March and April. Rye grass pasture appeared in programed solutions in small, varying amounts for cows freshening in January through March, June through September and

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[28]The reader should keep in mind that five pounds of 14 per cent protein dairy feed per cow are fed daily except during the first dry month and are not analyzed by the study.

[29]See Appendix Table A-XII for case number identification code.

TABLE VII

PROGRAMED RESULTS FOR GROUPS OF 100 DAIRY COWS, EACH GROUP FRESHENING IN A DIFFERENT MONTH OF THE YEAR AND PRODUCING 8,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - QUANTITY PER ACTIVITY PER YEAR[a]

	Month of Freshening[b]											
Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pasture												
Alfalfa	125	136	155	169	181	172	149	138	109	138	135	135
Oats	-	-	64	40	-	-	-	-	-	-	-	-
Rye Grass	11	11	2	-	-	16	27	16	33	-	2	-
Rye-Vetch	33	25	-	8	14	-	-	-	-	-	2	17
Hay												
Alfalfa	31	31	6	8	22	17	27	31	29	36	39	35
Bermuda	3	3	4	2	2	3	3	4	7	6	4	3
Bermuda-Hop Clover	-	-	10	2	1	2	2	4	28	-	-	-
Dry Grass												
Bermuda	93	86	87	80	75	71	79	94	51	103	100	99
Native	-	-	-	37	-	39	-	-	-	-	-	-
Concentrates												
14% Protein Dairy Feed	-	-	24	5	43	14	8	21	34	-	-	-
Land Use												
Class 1	156	167	161	177	203	189	176	169	138	174	174	170
Class 2	140	125	167	177	92	92	111	118	119	109	108	119
Class 3	-	-	-	37	-	39	-	-	-	-	-	-
Total Land	296	292	328	391	295	320	287	287	257	283	282	289
Programed Cost[c]	$5143	$5087	$5222	$4889	$5004	$4687	$4783	$5041	$5510	$5096	$5133	$5140

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]Each month of freshening represents a separate case study. January freshening represents case number 1 01 01, while December freshening represents case number 1 01 12.

[c]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

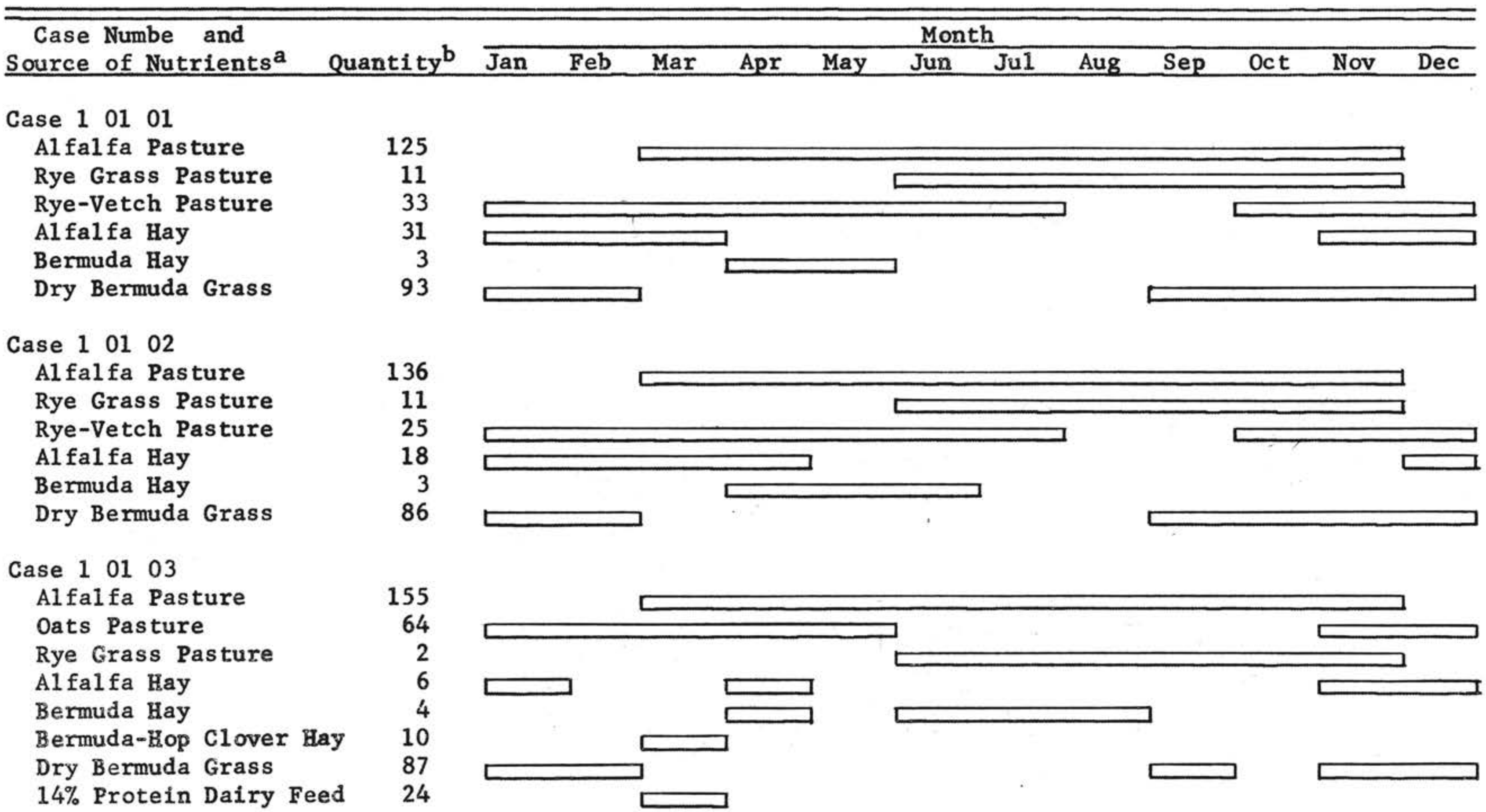
November. Cows freshening in January, February, April, May, November, and December utilized rye-vetch pasture. Small, varying quantities of bermuda-hop clover hay as well as additional concentrate appeared in solutions for freshening dates of March through September.

Roughage systems for the case solutions summarized in Table VII are presented in Figures 2 through 5. Monthly distribution of hay feeding is tabulated in Appendix Table A-XVII.

Figure 2 indicates that cases 1 01 01, 1 01 02, and 1 01 03 provide pasture the complete year. In each case, a large acreage of alfalfa pasture was available from March through November. Small quantities of rye grass pasture supplemented the alfalfa pasture from June to November. Cases 1 01 01 and 1 01 02 contained a sizable quantity of rye-vetch as a third pasture. It was the only growing pasture available in January, February, and December. The rye-vetch was also pastured in March through July, and in October and November. Case 1 01 03 employed 64 acres of oats as the third pasture. It provided pasture from November to the following May.

The three cases presented in Figure 2 utilized varying quantities of alfalfa hay during the winter months. Small quantities of bermuda hay were fed in April and May for case 1 01 01, in April through June for case 1 01 02, and in April, June, July, and August for case 1 01 03. In each of the three cases illustrated, dry bermuda grass pasture was used in the fall and winter months.

Case 1 01 03 used 10 acres of bermuda-hop clover hay and 2,400 pounds of 14 per cent protein dairy feed during March, the first month of lactation.



[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 2. Roughage Systems for Low Producing Dairy Cows Freshening in January, February, and March

Figure 3 illustrates the optimum roughage system for cows freshening in April, May, and June. These cases utilized alfalfa pasture in the same manner as the first three cases did. Case 1 01 05 had the largest acreage of alfalfa pasture with 181 acres.

Cases 1 01 04 and 1 01 05 used 8 and 14 acres respectively of rye-vetch pasture which produces from October to the following July. Cows freshening in April used 40 acres of oats pasture as a third pasture. It produces from November through the following May. The solution for case 1 01 06 contained 16 acres of rye grass pasture which produces from June to November.

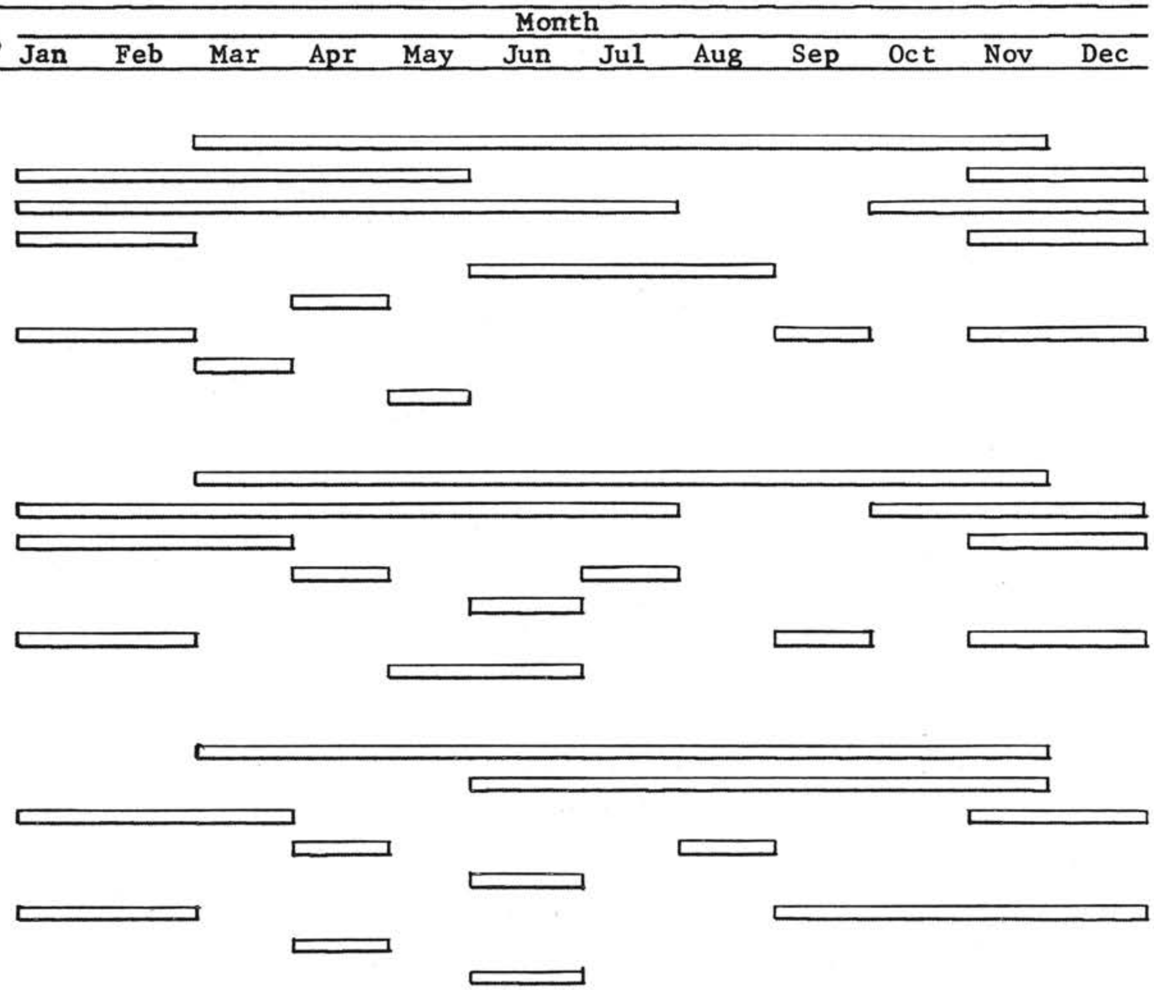
All solutions illustrated in Figure 3 fed alfalfa hay in January, February, November, and December. Case 1 01 05 also required the feeding of alfalfa hay in March. Bermuda hay was fed in each of the three cases in small quantities during intermittent months from April to August to supplement the pasture program. Very small quantities of bermuda-hop clover hay were fed the first or second month of lactation in each case.

Dry grass pasture, mostly bermuda, was grazed during the fall and winter months. Dry bermuda grass was the only pasture available in December, January, and February for case 1 01 06, while cows freshening in April and May had growing pasture available throughout the year.

Solutions for cows freshening in April, May, and June indicated additional 14 per cent protein dairy feed was fed during the first or second month of lactation.

The optimum roughage systems for low producing dairy cows freshening in July, August, and September are presented in Figure 4. These solutions were characterized by alfalfa and rye grass pasture during the

Case Number and Source of Nutrients[a]	Quantity[b]
Case 1 01 04	
Alfalfa Pasture	169
Oats Pasture	40
Rye-Vetch Pasture	8
Alfalfa Hay	8
Bermuda Hay	2
Bermuda-Hop Clover Hay	2
Dry Bermuda Grass	80
Dry Native Grass	37
14% Protein Dairy Feed	5
Case 1 01 05	
Alfalfa Pasture	181
Rye-Vetch Pasture	14
Alfalfa Hay	22
Bermuda Hay	2
Bermuda-Hop Clover Hay	1
Dry Bermuda Grass	75
14% Protein Dairy Feed	43
Case 1 01 06	
Alfalfa Pasture	172
Rye Grass Pasture	16
Alfalfa Hay	17
Bermuda Hay	3
Bermuda-Hop Clover Hay	2
Dry Bermuda Grass	71
Dry Native Grass	39
14% Protein Dairy Feed	14

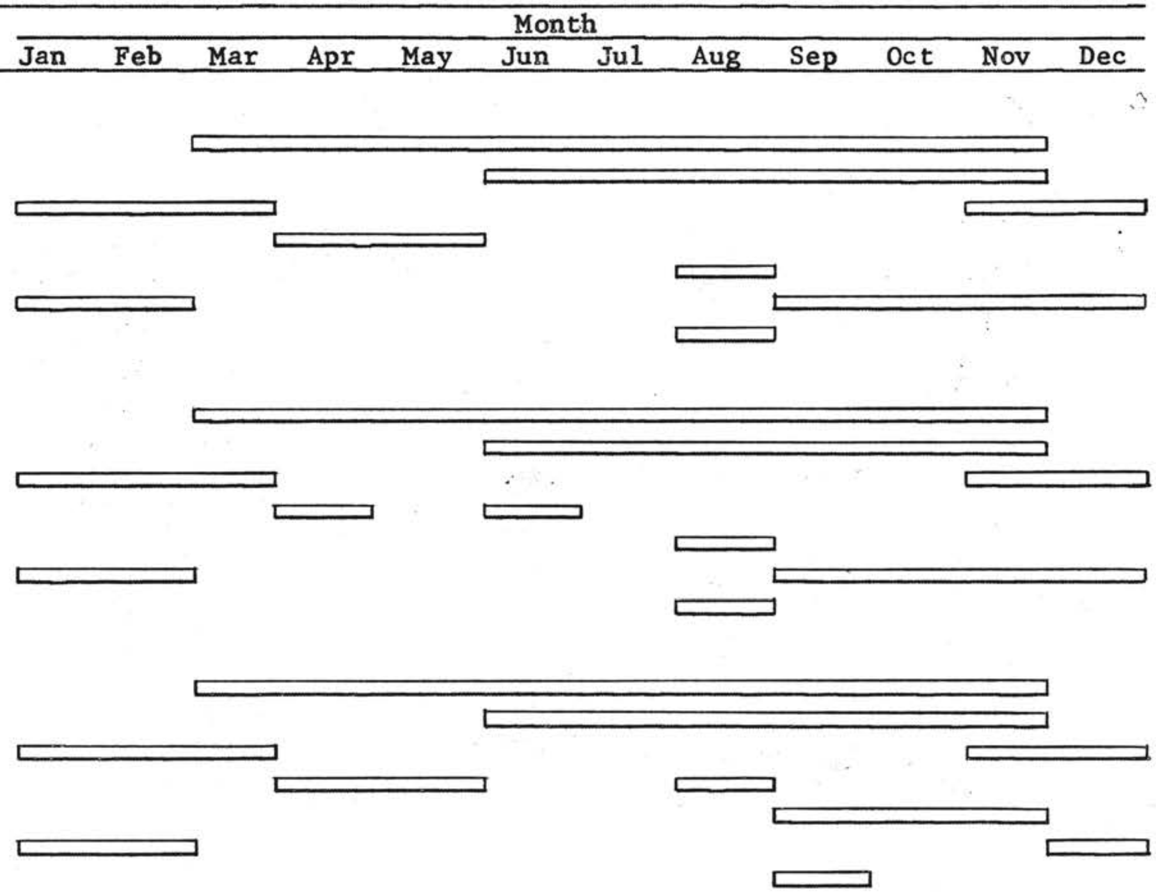


[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 3. Roughage Systems for Low Producing Dairy Cows Freshening in April, May, and June.

Case Number and Source of Nutrients[a]	Quantity[b]
Case 1 01 07	
Alfalfa Pasture	149
Rye Grass Pasture	27
Alfalfa Hay	27
Bermuda Hay	3
Bermuda-Hop Clover Hay	2
Dry Bermuda Grass	79
14% Protein Dairy Feed	8
Case 1 01 08	
Alfalfa Pasture	138
Rye Grass Pasture	16
Alfalfa Hay	31
Bermuda Hay	4
Bermuda-Hop Clover Hay	4
Dry Bermuda Grass	94
14% Protein Dairy Feed	21
Case 1 01 09	
Alfalfa Pasture	109
Rye Grass Pasture	33
Alfalfa Hay	29
Bermuda Hay	7
Bermuda-Hop Clover Hay	28
Dry Bermuda Grass	51
14% Protein Dairy Feed	34



[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 4. Roughage Systems for Low Producing Dairy Cows Freshening in July, August, and September.

growing season, while dry bermuda grass and alfalfa hay provided the required nutrients in December, January, and February. Small quantities of bermuda hay supplemented the pasture system from April to August. Alfalfa hay feeding was also required during March in each case to supplement the alfalfa pasture in its first month of production. Each solution illustrated in Figure 4 required the feeding of additional concentrates in the first or second month of lactation.

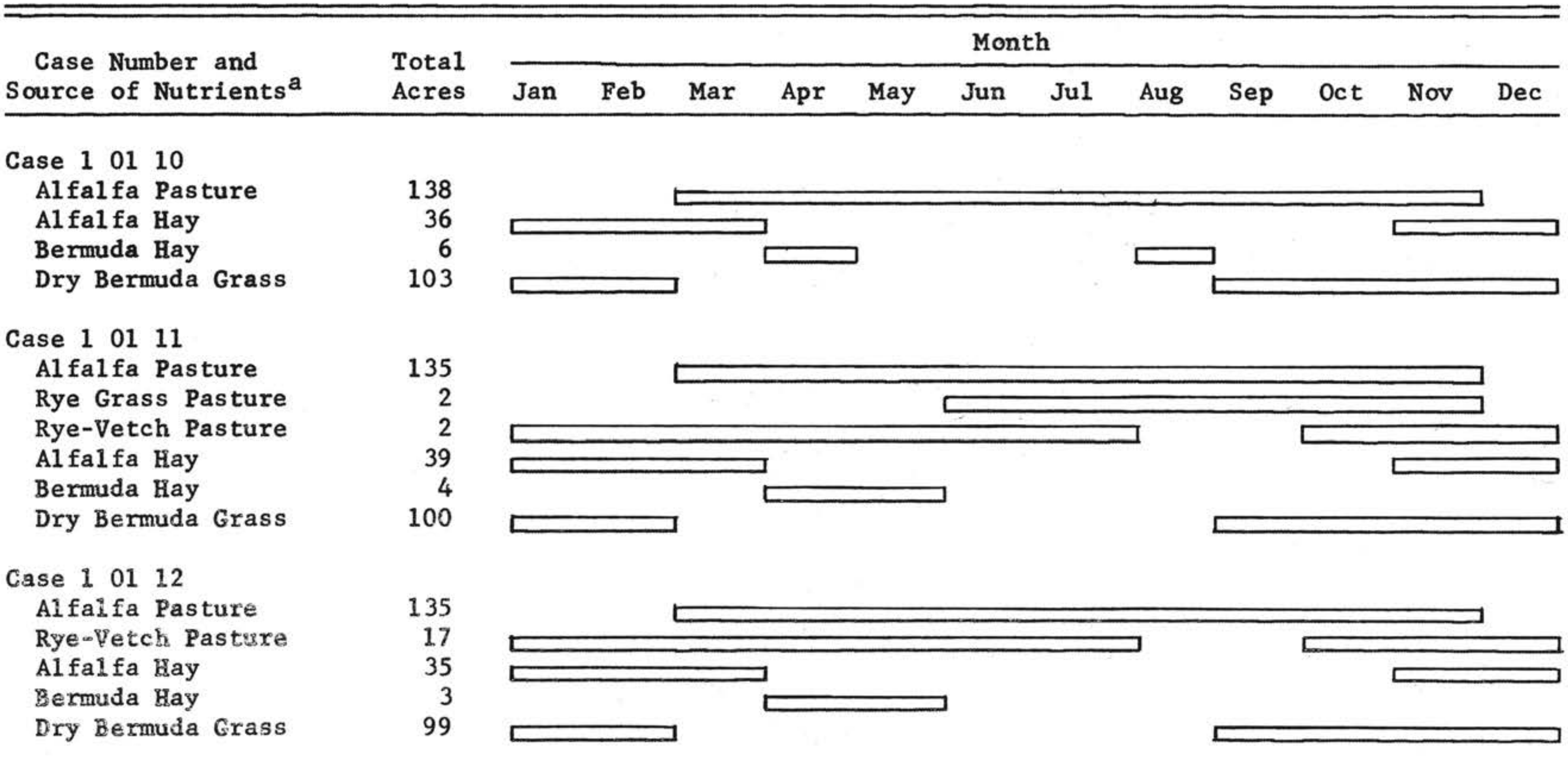
Optimum solutions for low producing dairy cows freshening in October, November, and December are presented in Figure 5. All three solutions utilized large acreages of alfalfa pasture producing from March to November. As with cows freshening in the three previous months, these low producing cows freshening in October, November, and December use large amounts of dry bermuda grass supplemented with alfalfa hay.

Small quantities of bermuda hay supplemented the pasture in April, May, June, and August in case 1 01 10, and in April and May in cases 1 01 11 and 1 01 12.

The solution for case 1 01 11 contained two acres of rye grass pasture and two acres of rye-vetch pasture. These small quantities would probably be replaced by additional acreage of roughages already in the solution in actual practice. Case 1 01 12 contained 17 acres of rye-vetch pasture which, together with the alfalfa pasture, provided growing pasture all year.

None of the solutions presented in Figure 5 required additional feeding of concentrate.

Land Use. Land requirements listed in Table VII for cows freshening in different months of the year are plotted in Figure 6. The use of Class 1 land varied from a high of 203 acres by 100 cows freshening in



[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

Figure 5. Roughage Systems for Low Producing Dairy Cows Freshening in October, November, and December

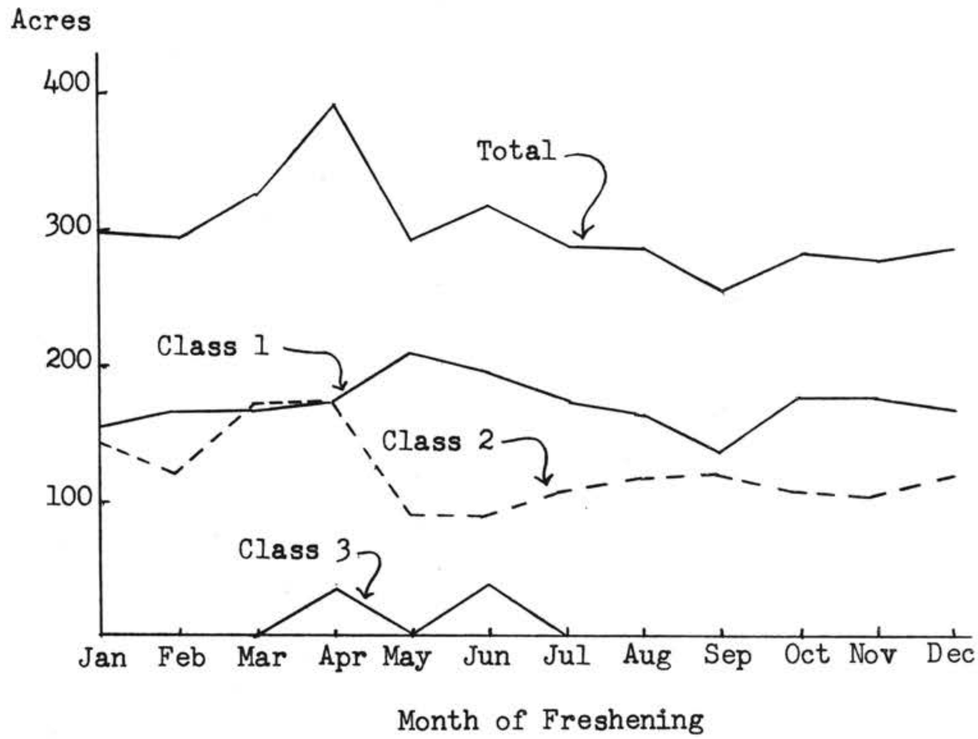


Figure 6. Land Use by Groups of 100 Low Producing Dairy Cows Freshening in Different Months

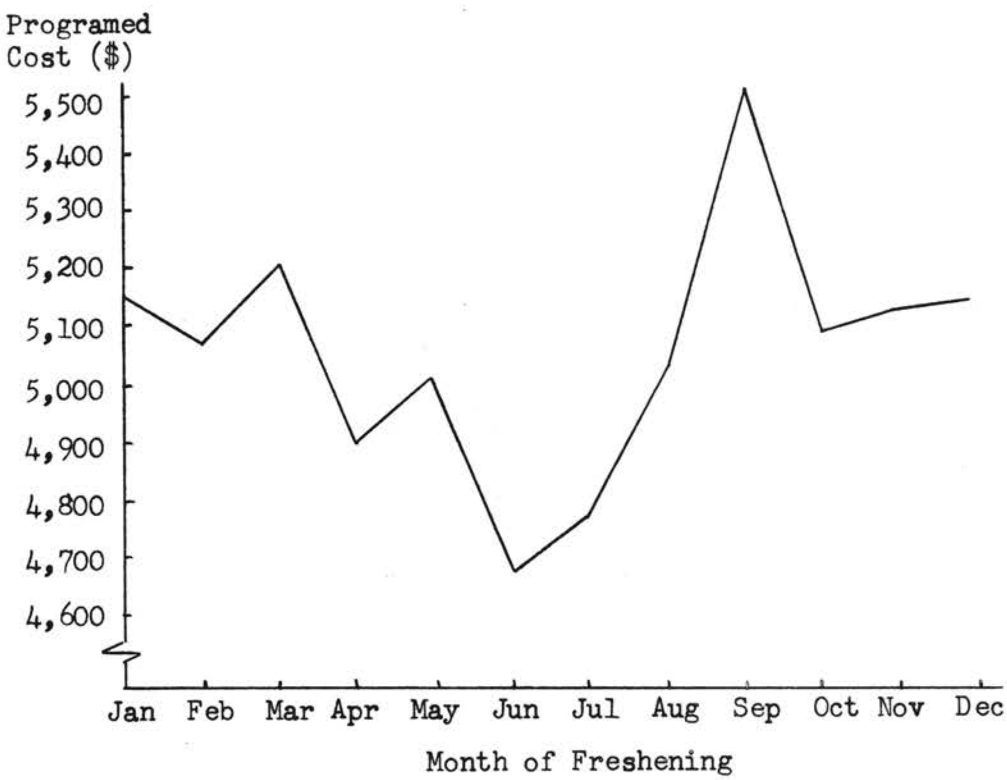


Figure 7. Programed Costs for Groups of 100 Low Producing Dairy Cows Freshening in Different Months

May to a low of 138 acres by 100 cows freshening in September. Cows freshening in April required the maximum quantity of Class 2 land, 177 acres. Class 2 land reached its minimum use of 92 acres by cows freshening in May and June. Class 3 land was used only by cows freshening in April and June with 37 and 39 acres respectively. Total land used varied from a high of 391 acres by 100 cows freshening in April to a low 257 acres by 100 cows freshening in September.

Programed Costs. The costs of the programed solutions tabulated in Table VII for the low producing dairy cows freshening in different months of the year are graphed in Figure 7. Costs presented in Figure 7 are net of the daily feeding of five pounds of grain for 11 months. The programed costs reached two peaks, one for cows freshening in March and the other for cows freshening in September. The September peak was somewhat higher than the March peak. These two high feed cost periods of freshening occurred because the cows were calving when transition must be made from summer to winter sources of roughage and neither summer nor winter pasture activities were in peak production. Costs were lower for the cows calving during the summer months because these cows could utilize efficient sources of nutrients such as alfalfa and rye grass pastures during the early months of lactation which have high nutrient requirements. The lowest cost solution was for June freshening with a cost of $4,687. The highest cost solution was for September freshening with a cost of $5,510. Thus, timing of freshening dates can affect feed cost by more than $8 per head per year. A maximum difference in cost of $8 per head, however, would amount to only .1 cent per pound of milk produced.

Near Optimal Solutions for March and September Freshening

The solutions in Table VII would change if the costs of some of the sources of roughage deviated moderately from the costs used by the study. The cost ranges of stability for these unstable processes are tabulated in Appendix Table A-XIV. Near optimum solutions for cows freshening in March and September were obtained by denying unstable processes in cases 1 01 03 and 1 01 09. The resulting near optimum solutions also contained unstable activities which in turn were denied. This process of denying unstable processes was continued until all processes in the solution were stable. For the purpose of the study, activities were considered stable when the upper and lower bounds of the shadow prices deviated from the programed cost by at least one dollar.

Dry grass pasture is a very low quality roughage although it does provide an efficient source of TDN. There is some question whether the producing dairy cow would be enticed to eat dry grass in the quantities appearing in programed solutions despite the fact that the dry grass was in a small enough volume to satisfy the stomach capacity requirement and of high enough TDN content to meet the energy requirement for these low producing cows. For these reasons, all dry grass processes were eliminated from consideration before the unstable processes were denied. The situations indicated (middle two digits of case numbers) for March and September freshening in the following results are numerated in Appendix Table A-XII.

Case 1 02 03 in Table VIII was the result of eliminating dry grass pasture from the roughage system of the low producing dairy cow freshening in March (case 1 01 03). Alfalfa pasture remained about the same with oats pasture decreasing to 43 acres. Eleven acres of barley pasture

TABLE VIII

PROGRAMED RESULTS FOR 100 DAIRY COWS FRESHENING IN MARCH AND SEPTEMBER, AND PRODUCING 8,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - DRY GRASS DENIED

	Case 1 02 03		Case 1 03 03		Case 1 04 03		Case 1 02 09	
Activity	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]
Pasture								
Alfalfa	No	158	Yes	-	No	159	No	109
Barley	No	11	Yes	-	Yes	-	No	-
Native	No	-	No	146	Yes	-	-	-
Oats	No	43	Yes	-	Yes	-	-	-
Rye Grass	No	-	No	51	Yes	-	No	33
Rye-Vetch	No	-	No	85	Yes	-	No	-
Hay								
Alfalfa	No	-	No	.1	Yes	-	No	9
Bermuda	No	41	No	44	No	47	No	47
Bermuda-Hop Clover	No	13	no	21	No	20	No	25
Native	No	-	No	-	No	8	No	-
Concentrates								
14% Protein Dairy Feed	No	31	No	150	No	110	No	34
Total Land		269		351		239		223
Programed Cost[b]		$6,039		$6,578		$6,139		$5,930

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

were added, and two acres of rye grass pasture eliminated. Bermuda hay replaced the dry grass, and the six acres of alfalfa hay were eliminated. Bermuda hop clover hay acreage increased from 10 to 13 acres. The feeding of additional 14 per cent protein dairy feed increased from 2,400 pounds to 3,100 pounds. Total land used decreased from 328 acres to 269 acres with programed cost increasing from $5,222 to $6,039.

If the cost of alfalfa pasture increased 88 cents, barley pasture 29 cents, and oats pasture 93 cents per acre, in case 1 02 03, the least cost combination of roughages would change. When these unstable activities are denied, 146 acres of native pasture, 51 acres of rye grass pasture, and 85 acres of rye-vetch pasture replace them in the solution. Alfalfa hay entered the solution at an uneconomically low level of one-tenth of an acre. Bermuda hay increased from 41 acres to 44 acres, and bermuda-hop clover hay increased from 13 to 21 acres. The feeding of additional 14 per cent protein dairy feed increased to 15,000 pounds, or 150 pounds per cow per year. The price increase of the unstable roughages forced the roughage system to utilize sources of roughage which provide the required combination of nutrients at higher costs, and the programed cost increased to $6,578.

All three pasture activities and alfalfa hay appearing in the solution of case 1 03 03 were unstable with shadow prices as indicated in Appendix Table A-XIV. Since most of the efficient pasture sources of nutrients were denied after native, rye grass, and rye-vetch pastures were denied, alfalfa pasture was permitted to come back into the system, and the result was case 1 04 03. All activities appearing in the solution of case 1 04 03 were stable. This solution, tabulated in Table VIII, contained 159 acres of alfalfa pasture as the only pasture.

Bermuda and bermuda-hop clover hay activities increased slightly over case 1 03 03, and native hay entered the roughage system at a level of eight acres. Additional concentrate feeding decreased from 150 to 110 pounds per cow. Permitting the highly efficient alfalfa pasture to re-enter the solution caused the programed cost to decrease $4.39 per cow, or from $6,578 to $6,139.

The solution for case 1 02 09 was the result of denying dry grass pasture from the roughage system of the low producing dairy cow freshening in September. All activities in the solution were stable. The 51 acres of dry grass pasture in case 1 01 09 were replaced by an additional 40 acres of bermuda hay. Dairy feed remained constant at the original 1.7 tons. Alfalfa hay production decreased 10 acres to a new level of 9 acres, and bermuda-hop clover hay decreased to 25 acres. Eliminating the dry grass pasture caused the programed cost to increase to $5,930. This represented an increase of $6.30 per cow per year.

Optimum and Near Optimum Solutions for March and September Freshening When No Class 1 Land is Available

Some dairy farms in the Oklahoma City milkshed have upland pasture and cash crop or Class 2 land, but do not have Class 1 land. Solutions for the low producing dairy cows freshening in March and September were analyzed with no Class 1 land available. Eliminating Class 1 land implies that no alfalfa crops are available for the roughage system. Dry grass pasture was not considered in this part of the analysis.

Case 1 05 03, presented in Table IX, was optimal for the low producing dairy cow freshening in March with no Class 1 land available to the farm and without pasturing dry grass. The pasture system was based

TABLE IX

PROGRAMED RESULTS FOR 100 DAIRY COWS FRESHENING IN MARCH AND PRODUCING 8,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - NO CLASS 1 LAND AVAILABLE

Activity	Case 1 05 03		Case 1 06 03		Case 1 07 03	
	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]
Pasture						
Barley	No	23	No	101	Yes	-
Native	No	228	Yes	-	Yes	-
Oats	No	88	Yes	-	Yes	-
Rye Grass	No	39	No	79	No	85
Rye-Vetch	No	-	No	71	Yes	-
Hay						
Bermuda	No	39	No	35	No	34
Bermuda-Hop Clover	No	18	No	11	No	21
Native	No	-	No	-	No	90
Concentrates						
14% Protein Dairy Feed	No	-	No	67	No	1526
Total Land		435		297		230
Programed Cost[b]		$6,468		$6,593		$10,566

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

on 228 acres of native pasture. Barley and oats provided pasture in the winter months with rye grass providing additional pasture in late summer and fall. Bermuda and bermuda-hop clover hay supplemented the pasture system with 39 and 18 acres respectively. No additional grain feeding was required with this system. The programed cost was $6,468. This represented a $429 increase over the optimal solution with Class 1 land available (case 1 02 03).

In case 1 06 03, cost increases of 36 cents and 80 cents per acre for native and oats pastures respectively caused the dairyman to replace these roughages with an additional 78 acres of barley pasture, 40 acres of rye grass pasture, and 71 acres of rye-vetch pasture. Hay production decreased from 57 acres to 46 acres, and an additional 67 pounds of 14 per cent protein dairy feed per cow were fed. Programed cost increased from $6,468 to $6,593. The solution of case 1 07 03 indicates that cost increases of less than one dollar per acre for barley and rye-vetch pastures caused them to be eliminated from the pasture system. Replacing the denied pastures were increases of 6 acres of rye grass pasture, 10 acres of bermuda-hop clover hay, and 90 acres of native hay. Grain feeding increased 1,459 pounds per cow per year. Bermuda hay production decreased to 34 acres. Denying the four pasture activities caused the programed cost to reach $10,566.

The roughage system for case 1 05 09 provided the required nutrients for the low producing dairy cow freshening in September, with no Class 1 land available to the farm, at a programed cost of $6,702. The pasture system contained 71 acres of native, 14 acres of oats, 70 acres of rye grass and 54 acres of rye-vetch pasture. This pasture system was supplemented with 52 acres of bermuda hay and 26 acres of bermuda-hop clover hay. The required roughage was produced on 287 acres of land. Cases 1 05 09, 1 06 09, and 1 08 09 are presented in Table X.

Per acre cost increases of 15 cents for native pasture and 19 cents for oats pasture in case 1 05 09 caused these two pastures to be denied. They were replaced, as indicated by case 1 06 09, by increases of 13 acres of rye grass pasture and 29 acres of rye-vetch pasture. Three acres of native hay entered the solution at $26.20 per acre. Bermuda and bermuda-hop clover hay production were each reduced by one acre. Grain feeding increased 39 pounds per cow per year, and programed cost increased only two cents per cow. Total land used decreased from 287 acres to 245 acres.

The upper bound shadow prices for the 83 acres of rye-vetch pasture in case 1 06 09 from Appendix Table A-XIV indicated a cost increase of 42 cents per acre made barley, at $20.27 per acre, a cheaper source of pasture than rye-vetch. Denying rye-vetch introduced 83 acres of barley pasture and added two more acres of rye grass in case 1 08 09. Bermuda and bermuda-hop clover hay decreased 12 and 8 acres respectively. Native hay acreage increased 36 acres, and an additional 110 pounds of grain were fed per cow per year. Total land use increased to 263 acres while programed cost increased $4.33 per cow to a total of $7,137.

Near Solution Activities Not Appearing in Case Solutions

The ZJ - CJ values of near solution "activities" discussed on page 29 are presented in Appendix Table A-XVI. These activities for the low producing cows include: native, barley, bermuda, and rye-vetch pastures; bermuda-hop clover hay; and 14 per cent protein dairy feed.

TABLE X

PROGRAMED RESULTS FOR 100 DAIRY COWS FRESHENING IN SEPTEMBER AND PRODUCING 8,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - NO CLASS ONE LAND AVAILABLE - DRY GRASS PASTURE DENIED

	Case 1 05 09		Case 1 06 09		Case 1 08 09	
Activity	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]
Pasture						
Barley	No	-	No	-	No	83
Native	No	71	Yes	-	Yes	-
Oats	No	14	Yes	-	Yes	-
Rye Grass	No	70	No	83	No	85
Rye-Vetch	No	54	No	83	Yes	-
Hay						
Bermuda	No	52	No	51	No	39
Bermuda-Hop Clover	No	26	No	25	No	17
Native	No	-	No	3	No	39
Concentrates						
14% Protein Dairy Feed	No	153	No	192	No	302
Total Land		287		245		263
Programed Cost[b]		$6,702		$6,704		$7,137

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

The near solution "activities" could be used to replace unstable activities in optimal solutions for months of freshening other than March and September. Solutions for March and September were stabilized by deriving near optimal solutions. For example, Appendix Table A-XIV indicates that oats pasture is unstable in case 1 01 04 and the entering activity is 14 per cent protein dairy feed fed in April. Appendix Table A-XVI indicates that up to 28 cwt. of 14 per cent protein dairy feed could replace oats pasture or other activities in the solution of case 1 01 04 at a cost penalty of 85 cents per cwt. of additional 14 per cent protein dairy feed.

Another example of how the dairyman might use the near solution activities is illustrated by case 1 01 01. Appendix Table A-XVI indicates up to 16 acres of native pasture could be substituted for sources of nutrients in the solution at a cost penalty of 84 cents per acre of native pasture used.

Programed Results for 1,300 Pound Dairy Cows Producing 11,000 Pounds of Four Per Cent FC Milk Per Year

The low producing dairy cow analyzed in the previous section was able to utilize very low quality roughages such as dry bermuda and native grass pasture. Cows of average producing ability (29.4 per cent efficiency) might not be able to consume the low quality roughages discussed above in quantities sufficient to maintain milk production, and dry grass activities were not considered in the analysis of the 29.4 per cent efficient dairy cows.

Eighteen roughage systems were derived which provide the required nutrients for average producing dairy cows freshening in different months of the year. The TDN and DP requirements were provided on a monthly basis and contained in a quantity of dry matter that could be consumed by the cow in the requirement month.

Optimum solutions were derived for groups of 100 average producing cows freshening in each of the 12 months. Near optimum solutions were programed for March and September freshening by denying unstable activities. Included in the analysis were 76 processes representing four hay and 11 pasture activities. These processes and activities are identified in Appendix Table A-XIII.

Optimal Solutions for Freshening in Each of the Twelve Months

Table XI summarizes the programed solutions for 12 groups of 100 average producing cows. Table XI indicates that all cases utilized alfalfa and rye grass pasture. The pasture system in each case was supplemented with bermuda and rye-vetch hay. In every case, cows required additional concentrate feeding above the minimum five pounds per day. Barley pasture served as winter pasture for cows freshening in the fall, winter, and early spring months, and oats pasture appeared in case solutions for February and March freshening. One to nine acres of alfalfa hay were produced for cows freshening from April to August. Small quantities of bermuda-hop clover hay appeared in case solutions for freshening in the summer months.

Roughage systems for the case solutions summarized in Table XI are presented in Figures 8 through 11. Monthly distribution of hay feeding is tabulated in Appendix Table A-XVIII.

Least cost roughage systems for January, February, and March freshening were similar. In each of these three cases, illustrated in Figure

TABLE XI

PROGRAMED RESULTS FOR GROUPS OF 100 DAIRY COWS, EACH GROUP FRESHENING IN A DIFFERENT MONTH OF THE YEAR AND PRODUCING 11,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - QUANTITY PER ACTIVITY PER YEAR[a]

	Month of Freshening[b]											
Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pasture												
Alfalfa	119	131	64	120	159	12	12	135	109	109	84	107
Barley	112	82	44	-	-	-	-	-	30	52	101	101
Oats	-	51	140	-	-	-	-	-	-	-	-	-
Rye Grass	25	17	77	58	26	93	93	44	33	14	25	25
Hay												
Alfalfa	-	-	-	1	2	9	9	5	-	-	-	-
Bermuda	47	48	31	58	64	82	85	48	41	39	34	39
Bermuda-Hop Clover	-	-	-	1	2	4	5	-	15	-	-	-
Rye-Vetch	35	11	17	24	4	39	34	40	51	78	78	52
Concentrates												
14% Protein Dairy Feed	236	607	866	1033	1054	841	827	1015	989	920	604	583
Land Use												
Class 1	119	131	64	121	161	21	21	140	109	109	84	107
Class 2	219	209	309	141	96	218	217	132	170	183	238	217
Total Land	338	340	373	262	257	239	238	272	279	292	322	324
Programed Cost[c]	$8752	$9419	$9964	$9523	$9482	$9999	$9953	$9845	$10364	$10737	$10214	$9714

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]Each month of freshening represents a separate case study. January freshening represents case number 2 01 01, while December freshening represents case number 2 01 12.

[c]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

8, alfalfa and rye grass pasture provided pasture during the summer growing season, while barley pasture served as a winter and spring pasture. Cases 2 01 02 and 2 01 03 also utilized large acreages of oats pasture in the winter and spring months. All three roughage systems presented in Figure 8 provided pasture in all 12 months of the year.

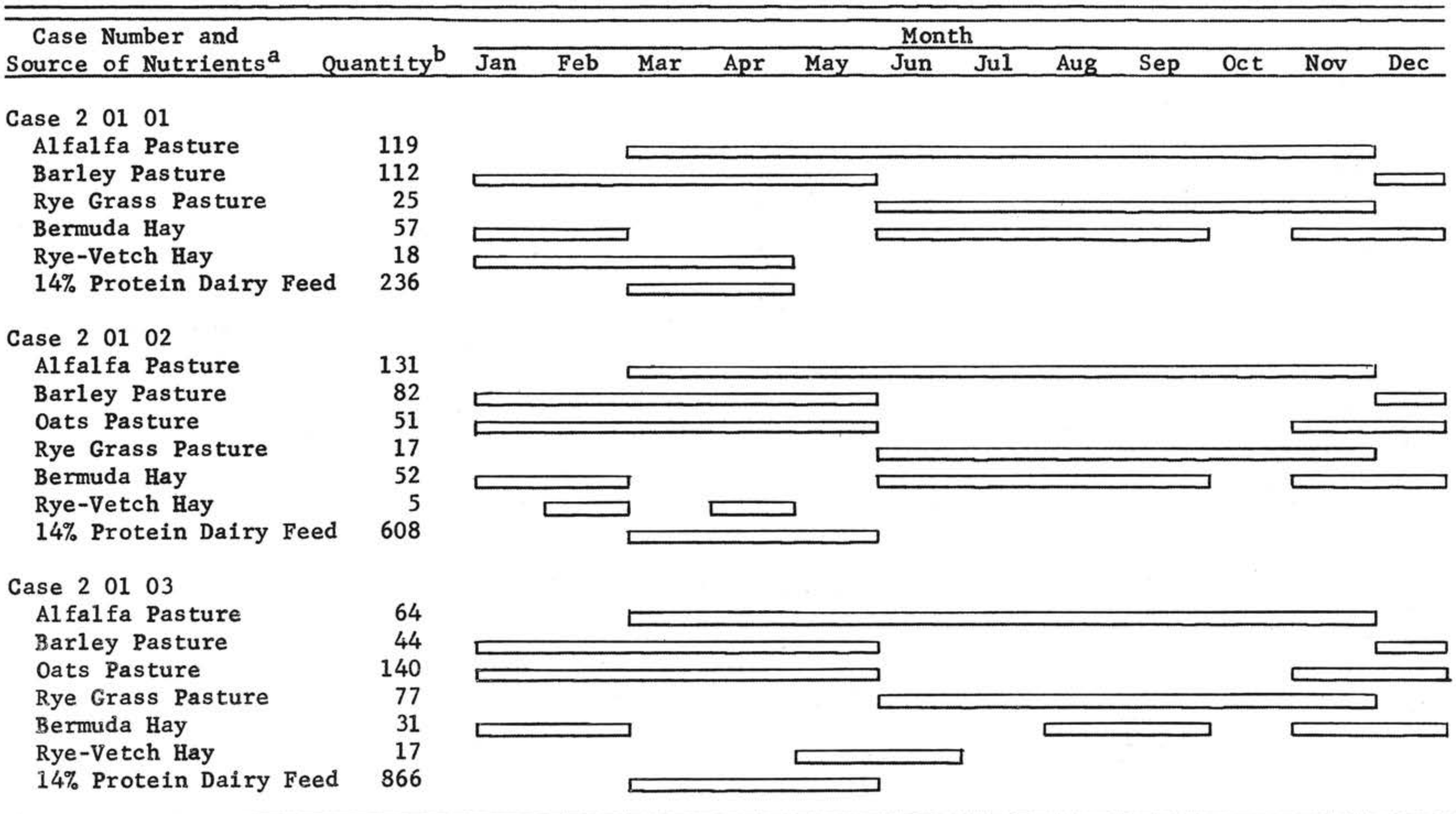
Case 2 01 01 supplemented the pasture system with 57 acres of bermuda and 18 acres of rye-vetch hay. Appendix Table A-XVIII indicates bermuda hay feeding ranged from 3.5 tons in July to 55.4 tons in December with none being required in March, April, May, and October. Rye-vetch hay was fed in quantities of 20.2 tons in January, 17.7 tons in February, and 8.1 tons in March.

Hay feeding for the cows freshening in February was very similar to January. Specific quantities by months are indicated in Appendix Table A-XVIII.

Case 2 01 03 required less bermuda hay acreage than did the two previous cases. Thirty-one acres of bermuda hay were produced and were fed in quantities of 19.8 tons in January, 26 tons in February, 17.6 tons in August, 12.3 tons in September, 33.9 tons in November, and 27.7 tons in December.

All three cases presented in Figure 8 required additional grain feeding in March and April, and cases 2 01 02 and 2 01 03 required additional grain in May.

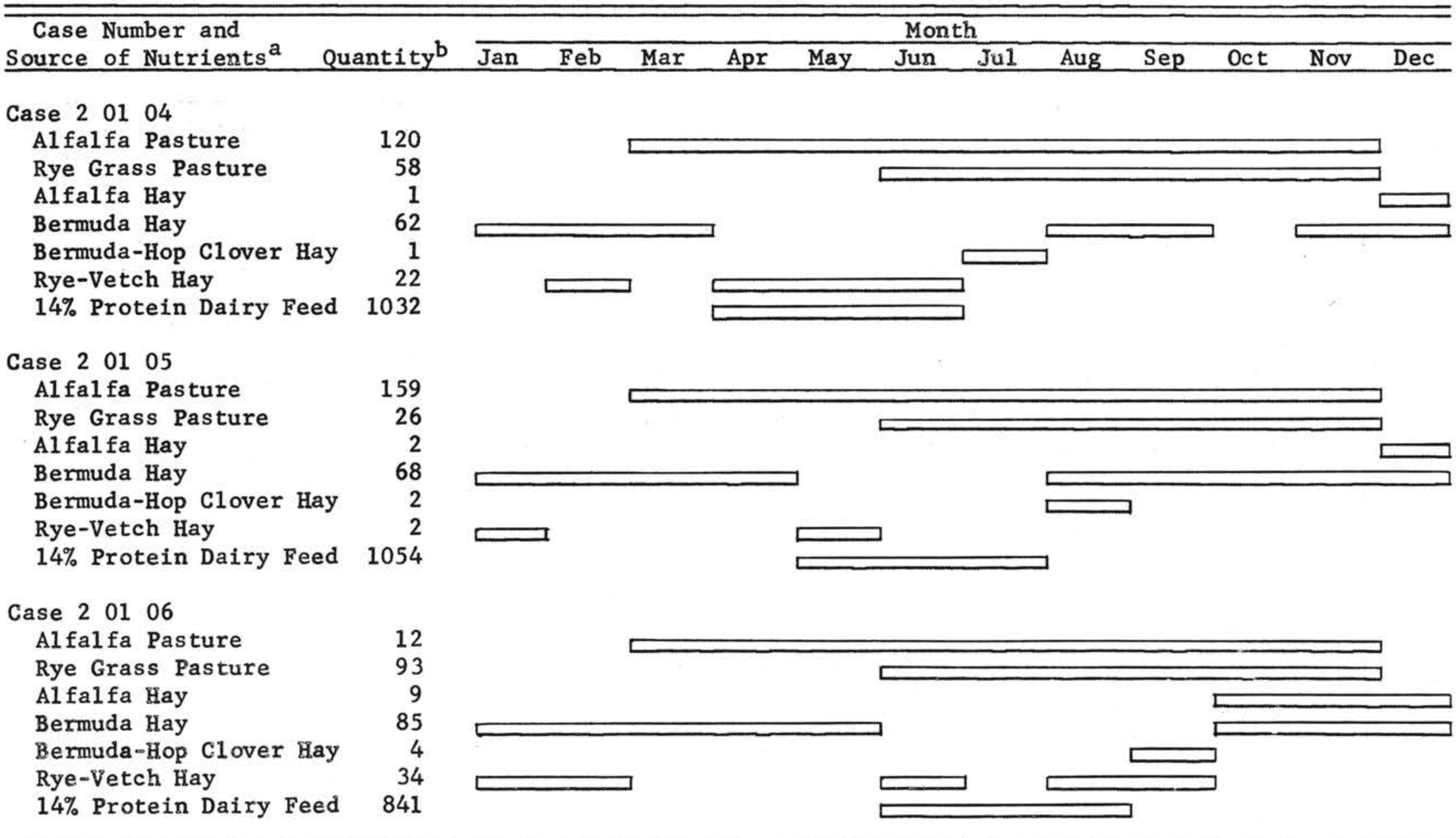
Programed solutions for cows freshening in April, May, and June are pictured in Figure 9. Each of these three cases utilized alfalfa and rye grass pasture during the growing season but did not provide pasture during the winter months. Small quantities of alfalfa hay were produced for feeding in the winter months, while small quantities of bermuda-hop



[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 8. Roughage Systems for Average Producing Dairy Cows Freshening in January, February, and March.



[a] The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b] Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 9. Roughage Systems for Average Producing Dairy Cows Freshening in April, May, and June

clover hay were produced for feeding in the summer months. Bermuda and rye-vetch provided most of the hay required by the solutions in Figure 9. Bermuda hay was the main source of nutrients in the winter months, with alfalfa and rye-vetch hay being fed for their high digestible protein content.

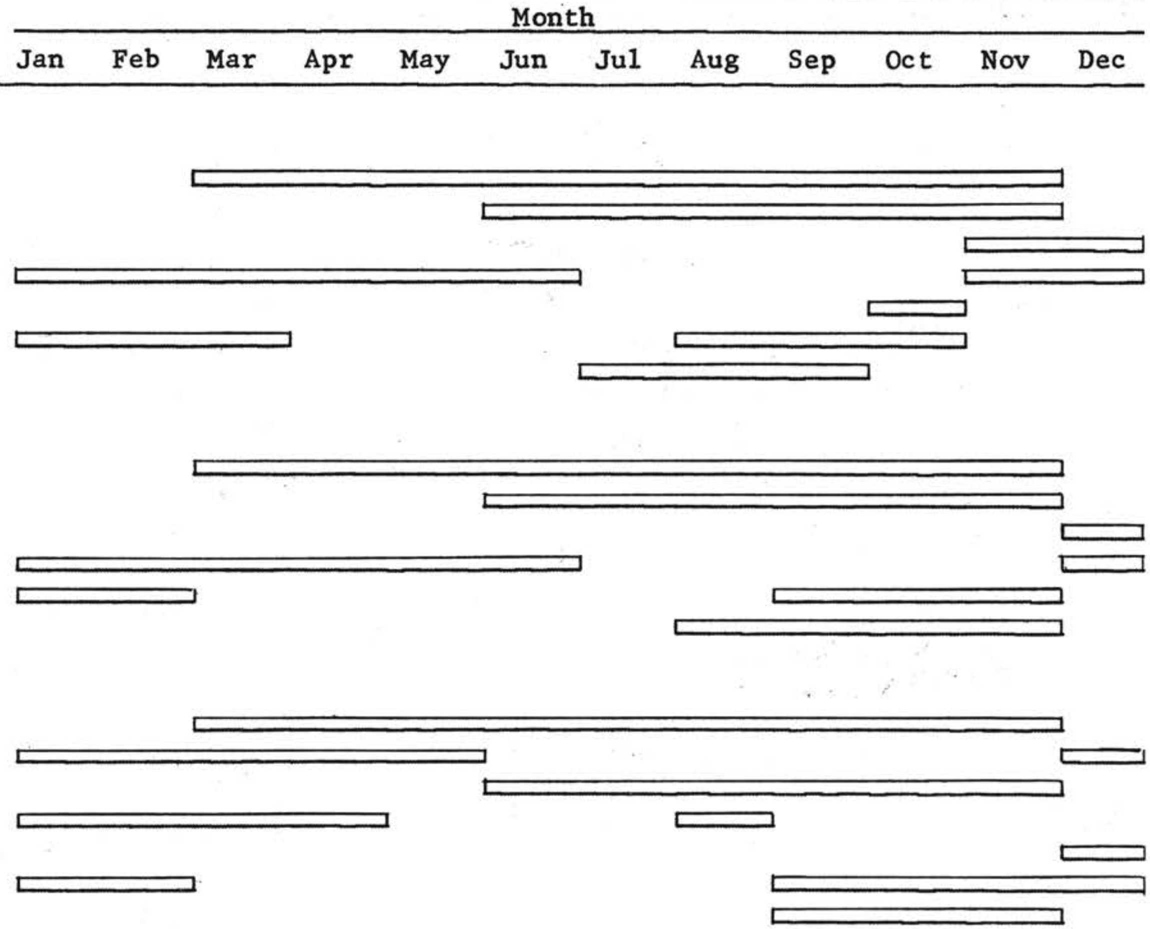
Each solution presented in Figure 9 required the feeding of 5.4 to 13.9 pounds above the minimum five pounds per day of 14 per cent protein dairy feed during the first three months of lactation.

Optimum roughage systems for average producing dairy cows freshening in July, August, and September are illustrated in Figure 10. These three cases provided alfalfa and rye grass pasture during the growing season, as did the three previous ones. Cows freshening in September utilized barley as a winter pasture. Cases 2 01 07 and 2 01 08 did not provide pasture in the winter months and relied on alfalfa, bermuda, and rye-vetch hay for the required nutrients during the winter months. Case 2 01 07 produced five acres of bermuda-hop clover hay to be fed in October, while case 2 01 09 produced 15 acres of bermuda-hop clover hay to be fed in December.

Each case presented in Figure 10 required from .7 to 13.1 pounds above the minimum five pounds per day of 14 per cent protein dairy feed to be fed during the first three to four months of lactation. Cows freshening in August required the greatest quantity of additional grain feeding with 101,500 pounds being fed per 100 cows during the first four months of lactation.

Least cost roughage systems for average producing dairy cows freshening in October, November, and December provided pasture in all 12 months as illustrated by Figure 11. Alfalfa and rye grass provided

Case Number and Source of Nutrients[a]	Quantity[b]
Case 2 01 07	
Alfalfa Pasture	12
Rye Grass Pasture	93
Alfalfa Hay	9
Bermuda Hay	85
Bermuda-Hop Clover Hay	5
Rye-Vetch Hay	34
14% Protein Dairy Feed	827
Case 2 01 08	
Alfalfa Pasture	135
Rye Grass Pasture	44
Alfalfa Hay	5
Bermuda Hay	48
Rye-Vetch Hay	40
14% Protein Dairy Feed	1015
Case 2 01 09	
Alfalfa Pasture	109
Barley Pasture	30
Rye Grass Pasture	33
Bermuda Hay	41
Bermuda-Hop Clover Hay	15
Rye-Vetch Hay	51
14% Protein Dairy Feed	989

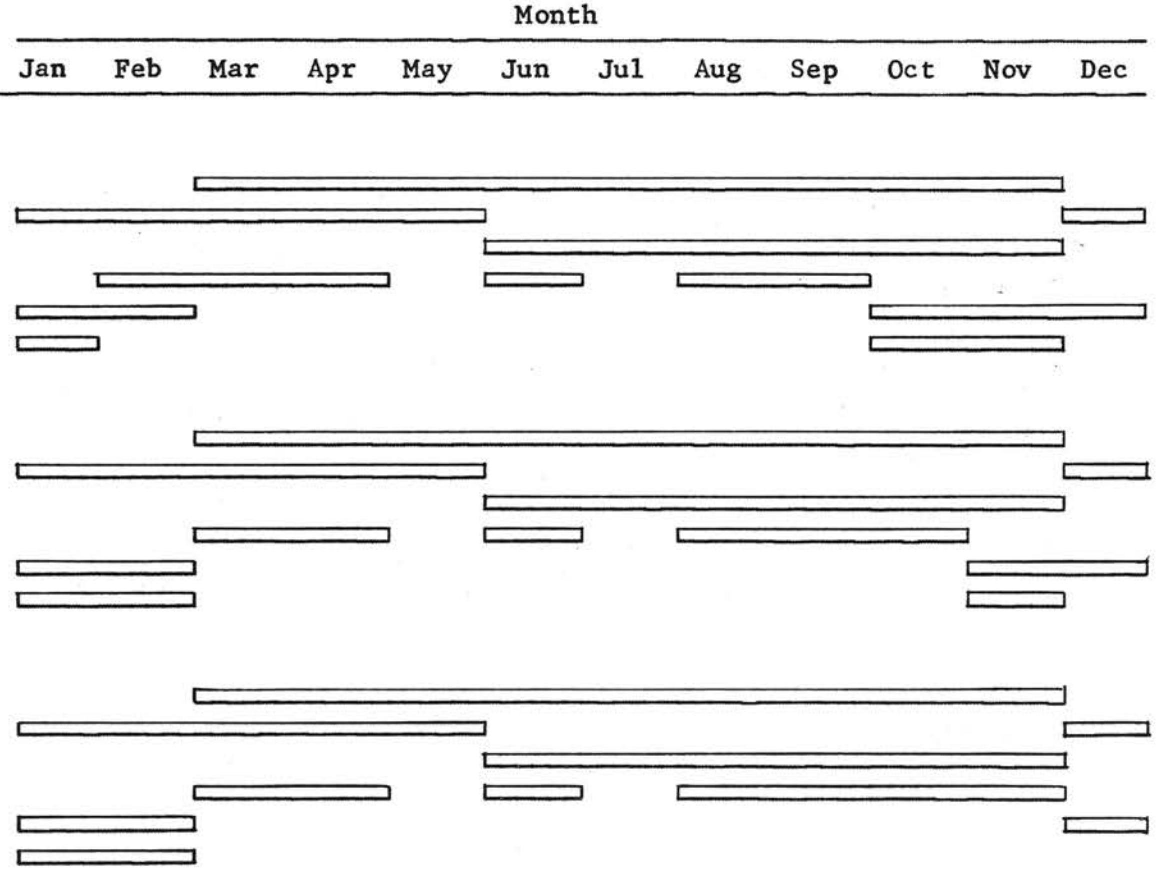


[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 10. Roughage Systems for Average Producing Dairy Cows Freshening in July, August, and September.

Case Number and Source of Nutrients[a]	Quantity[b]
Case 1 01 10	
Alfalfa Pasture	109
Barley Pasture	52
Rye Grass Pasture	14
Bermuda Hay	39
Rye-Vetch Hay	78
14% Protein Dairy Feed	920
Case 1 01 11	
Alfalfa Pasture	84
Barley Pasture	101
Rye Grass Pasture	25
Bermuda Hay	34
Rye-Vetch Hay	78
14% Protein Dairy Feed	604
Case 1 01 12	
Alfalfa Pasture	107
Barley Pasture	101
Rye Grass Pasture	25
Bermuda Hay	39
Rye-Vetch Hay	52
14% Protein Dairy Feed	583



[a]The daily feeding of five pounds of 14% protein dairy feed for 336 days is not included in this figure.

[b]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

Figure 11. Roughage Systems for Average Producing Dairy Cows Freshening in October, November, and December

pasture during the summer growing season while barley provided winter pasture in each case. Bermuda and rye-vetch hay supplemented the pasture system in months indicated by Figure 11. Specific quantities of hay fed in each month are tabulated in Appendix Table A-XVIII. Each solution presented in Figure 11 required from .5 to 13.2 pounds per cow per day above the minimum five pounds per day of 14 per cent protein dairy feed during the first four months of lactation.

Land Use. Land utilization by the optimum roughage systems for average cows is graphed in Figure 12. No Class 3 land was used. Class 1 and Class 2 land use was inversely correlated. That is, when Class 1 land use was down, Class 2 land use was up, and vice versa. However, Class 2 land use exceeded Class 1 land use by cows freshening in every month except May and August. March freshening required the greatest total acreage with 373 acres, while July freshening required the least acreage with 238 acres.

Programed Cost. The programed cost of cases 2 01 01 through 2 01 12 is plotted in Figure 13. As with the low producing dairy cows, the costs seemed to reach two peaks, one in the spring and one in the fall when the transition must be made from winter to summer sources of roughages and vice versa. However, October freshening resulted in the highest feed costs, with a programed cost of $107.37 per cow. There was an apparent upward trend in feed costs from a low of $87.52 per cow in January to the high of October. Programed costs then decreased to $97.14 per cow in December. Feed cost was apparently not correlated with the quantity of land used. The highest land requirement was associated with March freshening and the lowest with July. The programed cost for March

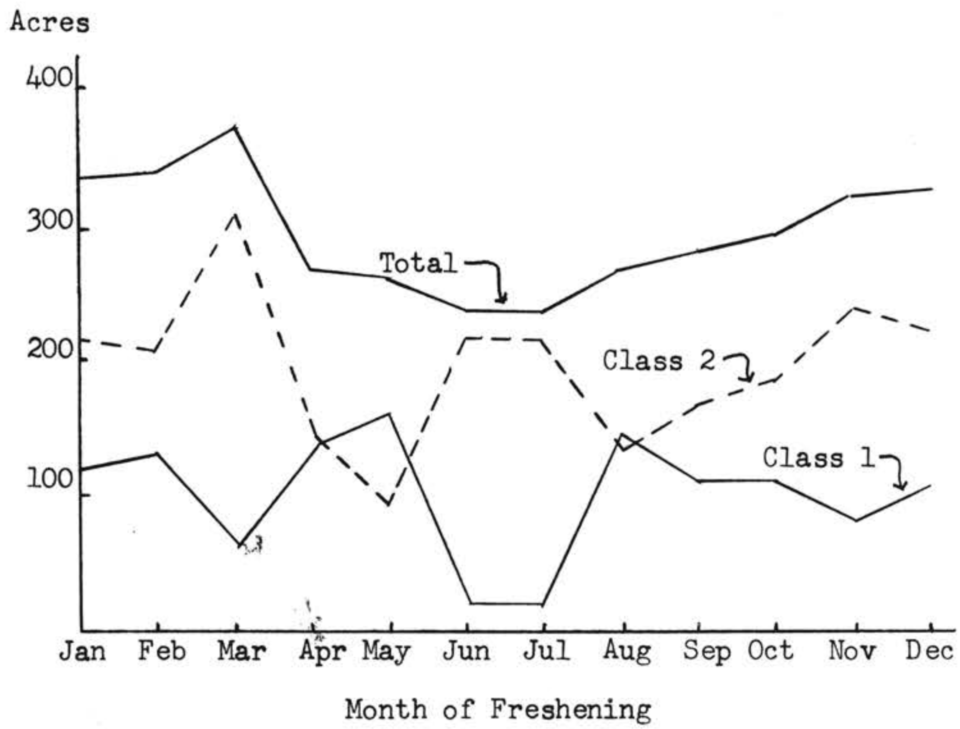


Figure 12. Land Use by Groups of 100 Average Producing Dairy Cows Freshening in Different Months

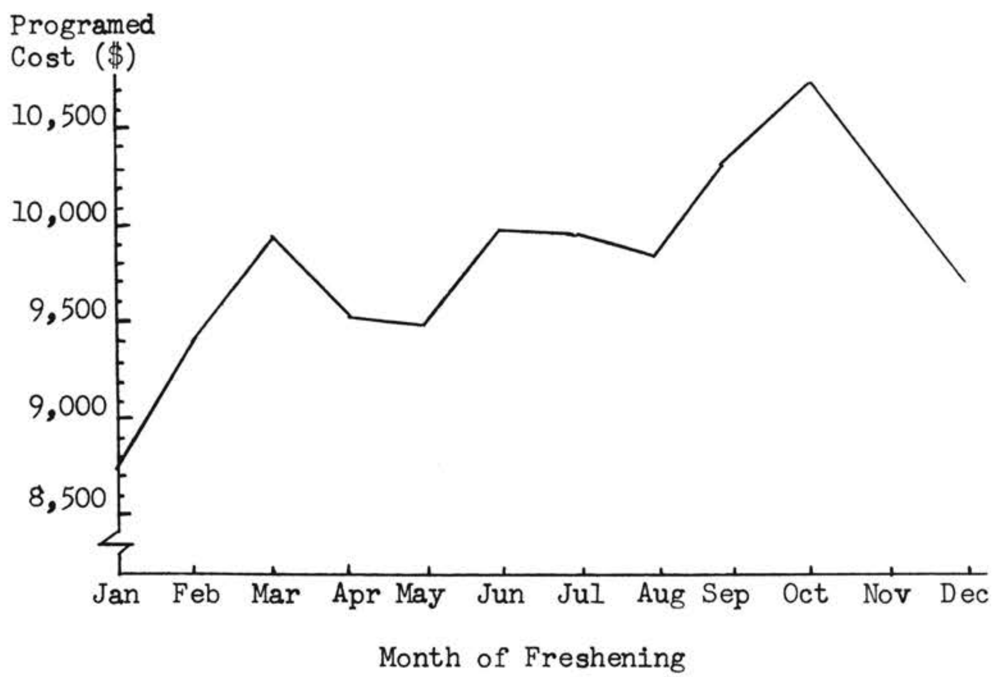


Figure 13. Programed Cost of Roughage Systems for Groups of 100 Average Producing Dairy Cows Freshening in Different Months

and July freshening were about equal. The cost pattern for average producing cows reaches a low in the winter compared to the summer low for low producing cows graphed in Figure 7.

Near Optimal Solutions for March and September Freshening

Barley, oats, and rye grass pasture as well as rye-vetch hay activities which appeared in case 2 01 03 were unstable. Small cost increases indicated in Appendix Table A-XV would have resulted in a different optimal solution. When these three pasture activities and rye-vetch hay were denied entry into the program, the result was case 2 09 03, presented in Table XII. An additional 120 acres of alfalfa pasture was incorporated in the roughage system, and 45 acres of bermuda pasture were introduced. Hay production changed from 31 acres of bermuda and 17 acres of rye-vetch to 50 acres of bermuda and 17 acres of bermuda-hop clover hay. Programed cost increased to $10,226. This represented an increase in cost of $2.62 per cow per year. However, 45 acres of permanent pasture were added which could be used as a holding area in the winter months.

A cost increase of one cent per acre for bermuda pasture appearing in case 2 09 03 would change the optimal solution. When bermuda pasture was denied entry into the roughage system, the result was case 2 10 03. The bermuda pasture was replaced by increases in hay and concentrate feeding as indicated by Table XII. Total land used decreased from 296 to 260 acres, while the programed cost increased 55 cents per cow per year. All activities appearing in case 2 10 03 were stable, but the desirable quality of providing permanent pasture was lost in the stabilizing process.

TABLE XII

PROGRAMED RESULTS FOR 100 DAIRY COWS FRESHENING IN MARCH AND SEPTEMBER, AND PRODUCING 11,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR

Activity	Case 2 09 03		Case 2 10 03		Case 2 11 09	
	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]
Pasture						
Alfalfa	No	184	No	184	Yes	-
Barley	Yes	-	Yes	-	Yes	-
Bermuda	No	45	Yes	-	No	-
Oats	Yes	-	Yes	-	No	-
Rye Grass	Yes	-	Yes	-	No	85
Hay						
Bermuda	No	50	No	53	No	70
Bermuda-Hop Clover	No	17	No	23	Yes	-
Rye-Vetch	Yes	-	Yes	-	No	89
Concentrates						
14% Protein Dairy Feed	No	1221	No	1237	No	905
Total Land		296		260		238
Programed Cost[b]		$10,226		$10,281		$10,686

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

Case 2 11 09 was the result of denying the unstable activities in the solution for the average producing dairy cow freshening in September. Alfalfa pasture, barley pasture, and bermuda-hop clover hay were unstable in case 2 01 09. These unstable activities were replaced by increases in rye grass pasture, bermuda hay, rye-vetch hay, and 14 per cent protein dairy feed by quantities indicated in Table XII. Total land use decreased by 41 acres, while programed cost increased by $3.22 per cow per year.

Optimal and Near Optimal Solutions for March and September Freshening When No Class 1 Land is Available

When no Class 1 land was available to the farm, the optimum roughage system for the average producing dairy cow freshening in March was represented by case 2 12 03, in Table XIII. The principle deviation of this solution from that of case 2 01 03 was that instead of 64 acres of alfalfa pasture produced on the Class 1 land, there were 188 acres of native pasture produced on Class 3 land. Land use increased 140 acres to a total of 513 acres. Programed cost was $10,273. This represented an increase of $3.09 per cow per year over the cost of feeding the same cows when Class 1 land was available.

Per acre cost increases of less than one dollar, as indicated by the shadow prices in Appendix Table A-XV, would have induced a new optimal roughage system for the production situation analyzed by case 2 12 03. When these three pasture crops were denied entry into the program, the resulting solution was case 2 13 03. Thirty-six acres of bermuda-lespedeza at a cost of $12.02 per acre entered the solution. Quantities of the remaining roughages increased, and programed cost

TABLE XIII

PROGRAMED RESULTS FOR 100 DAIRY COWS FRESHENING IN MARCH AND PRODUCING 11,000 POUNDS OF FOUR PER CENT FC MILK PER YEAR - NO CLASS 1 LAND AVAILABLE

	Case 2 12 03		Case 2 13 03		Case 2 14 03	
Activity	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]	Activity Denied?	Quantity[a]
Pasture						
Barley	No	31	Yes	-	Yes	-
Bermuda-Lespedeza	No	-	No	36	Yes	-
Native	No	188	Yes	-	Yes	-
Oats	No	185	Yes	-	Yes	-
Rye Grass	No	66	No	93	Yes	-
Sudan	No	-	No	-	No	167
Hay						
Bermuda	No	28	No	58	No	59
Bermuda-Hop Clover	No	-	No	-	No	5
Rye-Vetch	No	15	No	82	No	82
Concentrates						
14% Protein Dairy Feed	No	848	No	996	No	977
Total Land		513		268		312
Programed Cost[b]		$10,273		$10,591		$11,394

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]The cost of the daily feeding of an additional five pounds of 14% protein dairy feed for 336 days or $5,292 must be added to the programed cost to obtain the total feed cost. See page 21 for explanation.

increased $3.18 per cow over case 2 12 03. Total land use decreased 245 acres, almost 50 per cent.

The two pasture activities in case 2 13 03 were unstable. When the bermuda-lespedeza and rye grass pasture were denied entry into the program, the resulting roughage system was represented by case 2 14 03. Sudan pasture, producing from June to November, was the only pasture available. Hay feeding was about the same as in case 2 13 03 with an additional five acres of bermuda-hop clover hay being produced. Concentrate feeding decreased slightly. Total cost increased by $8.03 per cow, and the land requirement increased .44 acres per cow.

The solution for the average producing dairy cow freshening in September, case 2 01 09, did not require any Class 1 land, even though it was not restricted from doing so. Therefore, case 2 01 09 was also the optimum roughage system for 100 average producing dairy cows freshening in September when no Class 1 land was available to the farm.

Near Solution Activities Not Appearing in Case Solutions

The ZJ - CJ values of near solution "activities" discussed on page 29 are presented in Appendix Table A-XVI. These activities which could be used to replace activities in the case solutions for the average producing cows with a small cost increase include: barley, native, oats, and rye-vetch pastures; and alfalfa and bermuda-hop clover hay. For example, Appendix Table A-XV indicates that in case 2 01 01 a cost increase of 38 cents per acre of alfalfa hay would have caused less of that activity to appear in the solution. The incoming activity was oats pasture. According to Appendix Table A-XVI, up to 63 acres of oats pasture could replace alfalfa pasture or other activities in case 2 01 01 at a cost increase of 17 cents per acre of oats pasture used.

Programed Solutions for Dairy Replacement Heifers

Twelve cases representing groups of 100 dairy replacement heifers born in different months of the year were analyzed. Eighty-four processes representing 12 sources of roughages were examined as indicated in Appendix Table A-XIII.

Most dairy farms in the Oklahoma City milkshed contain considerable acreages of native pasture land. Dairymen typically use this lower quality roughage for replacement heifers, keeping the higher quality roughages available for the producing dairy cows. Also, most of the programs analyzed by this study for producing dairy cows did not utilize native pasture land. Therefore, for the purpose of the study, replacement heifers were denied all pasture except native pasture.

To conserve storage space in the computer and thus permit more activities to be analyzed, the replacement programs were analyzed on a basis of six feeding periods to the year, consisting of 61 days each. Requirements of heifers born in different months, however, remain as presented in Appendix Tables A-V and A-VI. They were simply condensed into six feeding periods for programing purposes.

Programed solutions for replacement heifers born in different months of the year are summarized in Table XIV. These roughage systems provide the required nutrients for replacement heifers from four months to twenty-four months of age.

Three sources of nutrients, native pasture, alfalfa hay, and bermuda hay, provided the required nutrients in each of the 12 cases.

TABLE XIV

PROGRAMED RESULTS FOR 100 REPLACEMENT HEIFERS BORN IN DIFFERENT MONTHS OF THE YEAR - ALL PASTURE EXCEPT NATIVE DENIED - ACRES PER ACTIVITY PER YEAR

Month of Birth[a]	Case Number	Activity: Alfalfa Hay (Class 1 Land)	Activity: Bermuda Hay (Class 2 Land)	Activity: Native Pasture (Class 3 Land)	Total Land	Programed Cost[b]
		Acres	Acres	Acres	Acres	Dollars
Jan	3 15 01	10	76	406	492	6,747
Feb	3 15 02	12	86	341	439	6,977
Mar	3 15 03	15	97	264	376	7,226
Apr	3 15 04	15	98	259	372	7,256
May	3 15 05	16	98	253	367	7,281
Jun	3 15 06	14	87	320	421	7,051
Jul	3 15 07	15	92	295	402	7,136
Aug	3 15 08	14	93	289	396	7,151
Sep	3 15 09	14	95	283	392	7,174
Oct	3 15 10	10	59	442	511	6,637
Nov	3 15 11	9	66	466	541	6,556
Dec	3 15 12	6	74	438	518	6,634

[a]Each month of birth is represented by a separate case number. For example, January birth is represented by case 3 15 01, while December birth is represented by case 3 15 12.

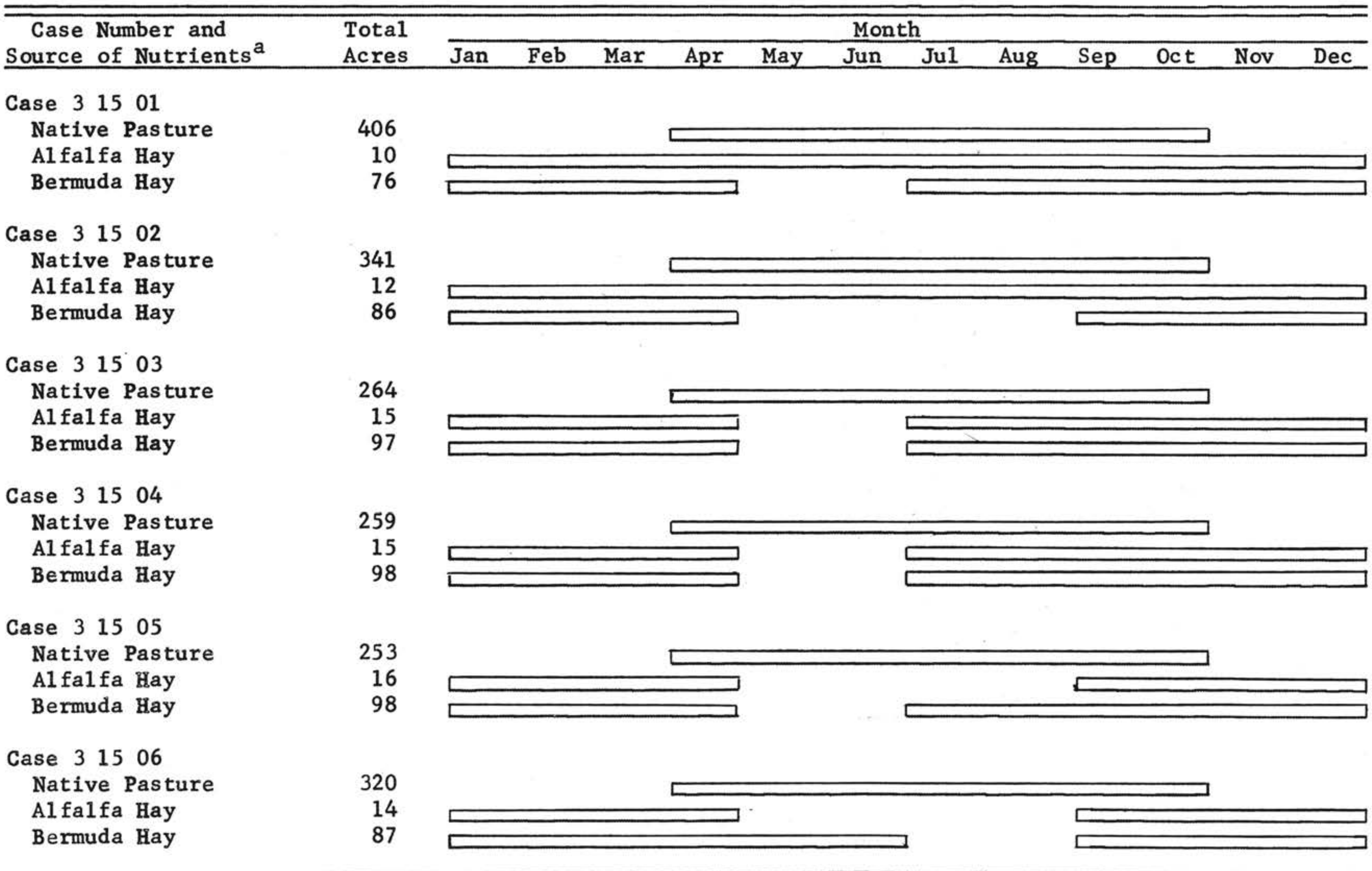
[b]A charge of $17.00 per head or $1,700.00 to cover the feed cost for the first four months of life must be added to the programed cost to obtain the total feed cost.

Native pasture is utilized at acreages ranging from a low of 253 acres by heifers born in May to 466 acres by heifers born in November. Alfalfa hay production ranges from a low of six acres for heifers born in December to a high of 16 acres for heifers born in May. The alfalfa hay is provided primarily for its high digestible protein content, while the major portion of the required nutrients are provided by the native pasture and bermuda hay. Bermuda hay acreage varies from a low of 59 acres for heifers born in October to a high of 98 acres for heifers born in April and May.

Roughage systems for the cases presented in Table XIV are illustrated in Figures 14 and 15, while the distribution of hay feeding is tabulated by tons per month in Appendix Table A-XIX. All activities in cases 3 15 01 to 3 15 12 are stable.

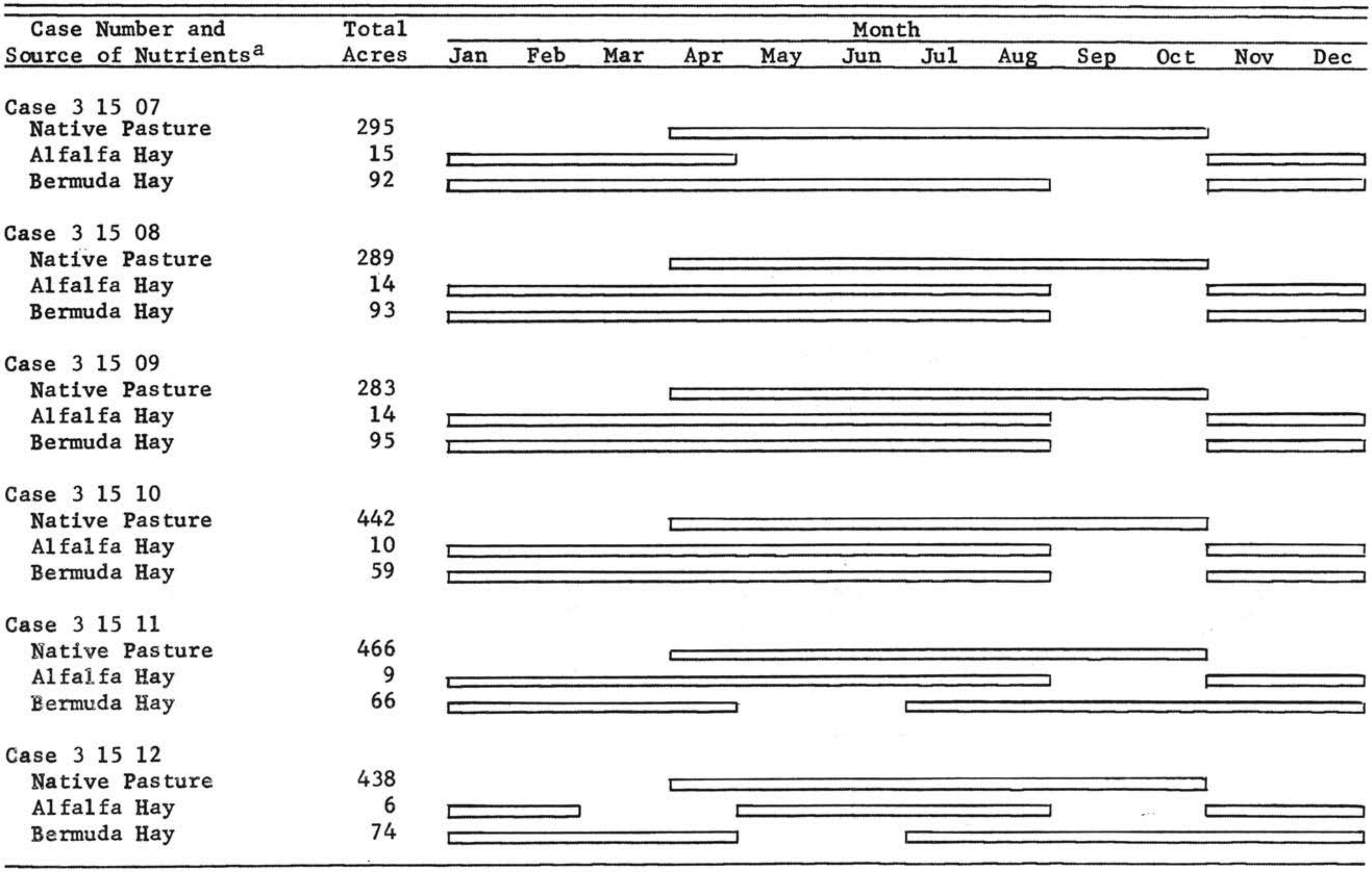
Land Use. Land utilization by cases 3 15 01 through 3 15 12 is graphed in Figure 16. The major portion of land used is the Class 3 land on which the native pasture is produced. Class 2 land is used to produce bermuda hay, primarily for its TDN value. A small quantity of Class 1 land is used in each case to produce alfalfa hay to provide adequate digestible protein. The land requirement for heifers born in the winter months is relatively high in comparison with the land requirements for heifers born in the early summer months.

Programed Cost. The programed cost of roughage systems for heifers born in each of the 12 months is shown in Figure 17. Apparently, the cost of the roughage systems was inversely correlated with the land requirement. When programed cost was at its highest level, i.e., a cost of $7,281 for May calving, land use was at its lowest level, 367 acres.



[a]This figure does not include the feeding program for the first four months of life.

Figure 14. Roughage Systems for Replacement Heifers Born in January Through June.



[a]This figure does not include the feeding program for the first four months of life.

Figure 15. Roughage Systems for Replacement Heifers Born in July Through December

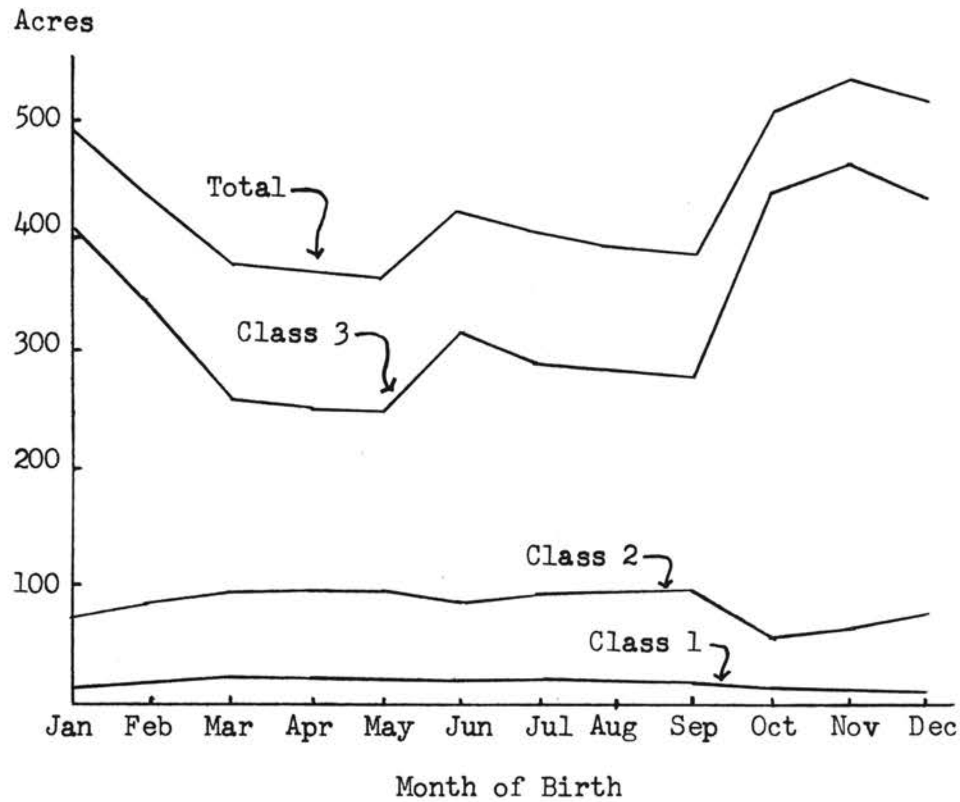


Figure 16. Land Use by Groups of 100 Dairy Replacement Heifers Born in Different Months

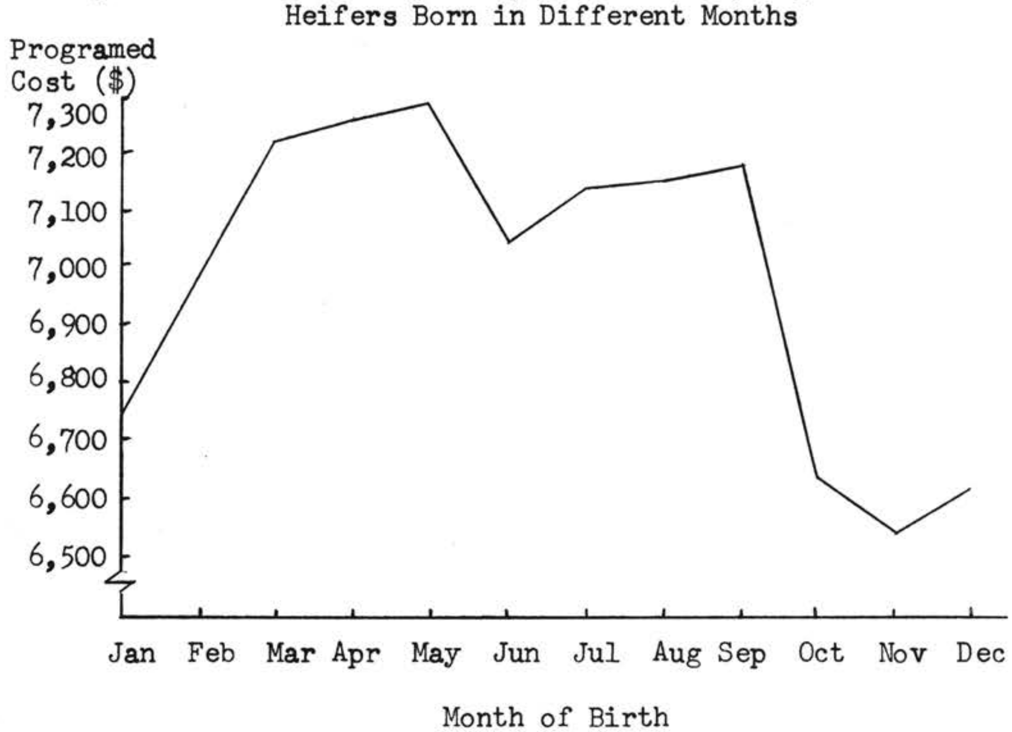


Figure 17. Programed Cost of Roughage Systems for Groups of 100 Dairy Replacement Heifers Born in Different Months

When programed cost was at its low point of $6,556 for heifers born in November, land use was at its highest level, 541 acres.

The requirements of heifers born in the winter months are closely correlated with the nutrient yields of native pasture. This reflects the opportunity to use relatively more low cost native pasture with heifers born in the winter months.

Roughage Systems for Dairy Herds

Roughage systems for dairy herds made up of classes of animals considered by the study can be derived by summing the roughage systems for individual animals.

The Dairy Herd Considered by the Study

The hypothetical dairy herd presented in Table XV was prepared for use by the study. This herd consisted of 100 producing dairy cows and 60 replacement heifers. Two-thirds of the cows were average producing cows, while one-third were low producers. Half of the heifers were over one year of age and half were under one year. A system of both spring and fall freshening was followed with cows freshening as indicated in Table XV.

The roughage system for the dairy herd is presented in Table XVI. It is a summation of the roughage systems of the individual animals in the herd. The programed cost net of the cost of the daily feeding of five pounds of 14 per cent protein dairy feed per cow for 336 days and the feed costs for replacement heifers during the first four months of life is $11,638. Total feed cost for the 100 cow herd with replacements

TABLE XV

COMPOSITION OF THE DAIRY HERD CONSIDERED BY THE STUDY

Animal Class and Month of Freshening or Birth																		
1,300 Pound Dairy Cows Producing 8,000 Pounds of 4% FCM at 24.7% Efficiency						1,300 Pound Dairy Cows Producing 11,000 Pounds of 4% FCM at 29.4% Efficiency												
Spring Freshening			Fall Freshening			Spring Freshening			Fall Freshening			Replacement Heifers Born in:[a]						Total Number of Animals in Herd
Feb	Mar	Apr	Aug	Sep	Oct	Feb	Mar	Apr	Aug	Sep	Oct	Feb	Mar	Apr	Aug	Sep	Oct	
4	8	4	4	9	4	8	17	8	8	18	8	7	15	8	7	15	8	
Class Totals																		
33						67						60						160

[a]Half of the replacement heifers are over one year of age, and half are under one year.

TABLE XVI

ROUGHAGE SYSTEM FOR THE DAIRY HERD
CONSIDERED BY THE STUDY

Source of Nutrients	Quantity[a]
Pasture Activities	
Alfalfa	116
Barley	24
Native	182
Oats	35
Rye Grass	34
Rye-Vetch	2
Hay Activities	
Alfalfa	16
Bermuda	84
Bermuda-Hop Clover	6
Rye-Vetch	24
Dry Bermuda Grass	26
14% Protein Dairy Feed	284
Land Use	
Class 1	132
Class 2	235
Class 3	182
Total Land	549
Programed Cost[b]	$11,638

[a]Quantity is measured in cwt. for 14% protein dairy feed and in acres otherwise.

[b]This figure does not include the daily feeding of five pounds of 14% protein dairy feed per cow per day for 336 days nor the feed cost for the replacement heifers for the first four months of life. Including these items would raise the total cost to $17,950.

was $17,950. Total land use was 549 acres with 132 acres of Class 1, 235 acres of Class 2, and 182 acres of Class 3 land.

Total Feed Costs of Optimal Solutions for Herds of Different Composition

Examples for dairy herds of various compositions could be worked out using the data from Tables VII, XI, and XIV. These roughage systems would result in total feed costs for cows and replacements as indicated in Table XVII. The data from Table XVII is presented graphically in Figure 18.

Table XVII and Figure 18 indicate feed costs for the low producing (24.7 per cent efficient) cows including replacements were lowest with April freshening at a cost of $15,254. The highest feed cost for the low producing cows and replacements resulted from September freshening with a total feed cost of $16,053. The total feed cost for these low producing animals remained fairly constant over winter and early summer freshening dates. Total feed cost increased with late summer freshening and reached its maximum with September freshening.

Feed costs for the average producing (29.4 per cent efficient) cows and their replacements trend upward from a low of $19,046 with January freshening to a high of $21,331 with October freshening. The maximum difference in range amounted to nearly $23 per cow per year for average producing cows compared to a range of about $8 per year for the low producers. A $23 range, expressed in terms of milk output, amounted to .21 cents per pound of milk produced for the average producing cows.

A program of spring freshening would have resulted in lower feed costs than would a program of fall freshening. This was true for both efficiency levels of production considered. However, feed cost

TABLE XVII

TOTAL FEED COSTS FOR GROUPS OF 100 DAIRY COWS WITH REPLACEMENTS: DERIVED FROM OPTIMAL ROUGHAGE SYSTEMS DEVELOPED BY THE STUDY[a]

Month of Freshening	Animal Units[b]	
	Low Producing Cows With Replacements	Average Producing Cows With Replacements
Jan	$15,437	$19,046
Feb	15,333	19,665
Mar	15,514	20,256
Apr	15,254	19,883
May	15,502	19,980
Jun	15,335	20,647
Jul	15,449	20,619
Aug	15,722	20,526
Sep	16,053	20,907
Oct	15,690	21,331
Nov	15,736	20,817
Dec	15,756	20,330

[a]This data represents the annual feed cost for the dairy cows and the feed cost for their replacements from birth to 24 months of age.

[b]Total per animal unit (cow and replacement) freshening in the i^{th} month = [feed cost for cow freshening in the i^{th} month] + .6 [feed cost of the heifer born in the i^{th} month]. Replacement heifers calve at 27 months of age.

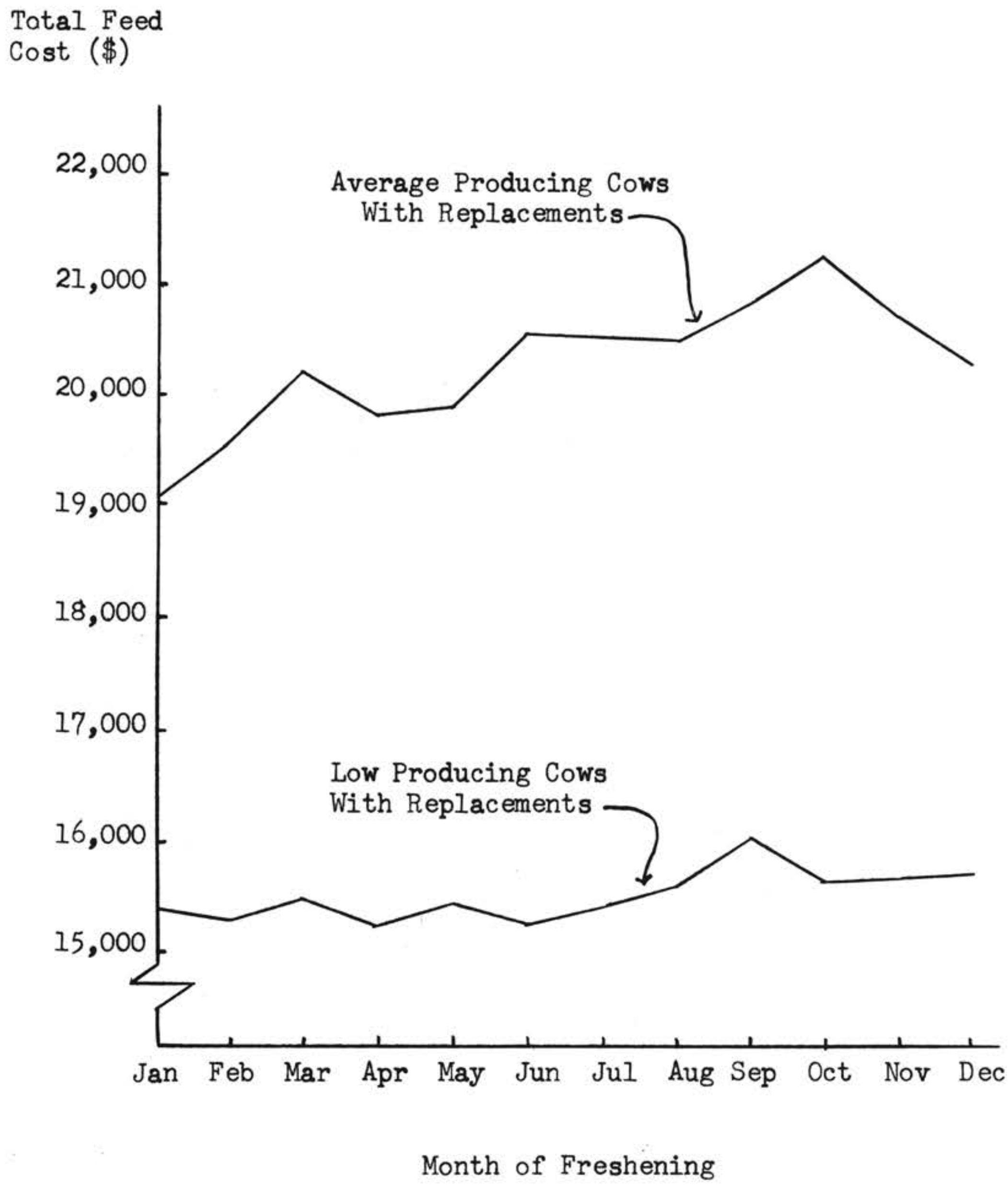


Figure 18. Total Feed Costs for Dairy Cows With Replacements: Derived From Optimal Roughage Systems Developed by The Study

deviations for both the low and average producing cows freshening in different months of the year may or may not be significant when compared to the monthly deviations in the price received for milk.

CHAPTER V

INTERPRETATIONS

Roughage systems were derived in Chapter IV which satisfied the nutrient requirements for the dairy animals considered by the study. The case solutions derived were estimates of the roughage systems the dairymen could have used to minimize costs, given the specific animal requirements and management situation. Several alternative, near optimal roughage systems for spring and fall freshening were derived, and near solution activities were presented which could be brought into the roughage system with small increases in cost.

While the specific animal requirements and management situations used for the analysis may not be realized in any one dairy herd in the Oklahoma City milkshed, the study provides rational approximations to the least cost roughage systems. The dairyman, through partial budgeting, can adapt the proposed roughage systems to fit his needs and situation. Also, from the results of the study certain generalizations can be made about the relative efficiency of roughages in use by dairymen.

Considered in the chapter are efficient sources of roughages, inefficient sources of roughages, the availability of pasture in the programed solutions, and land use.

Efficient Sources of Nutrients

Of the 62 sources of nutrients in use by dairymen in the Oklahoma City milkshed, 37 were eliminated from consideration on the basis of prior research. Of the 25 analyzed, 17 appeared in programed solutions. These 17 efficient sources of nutrients are presented in Table XVIII with the cost per pound of TDN and DP provided by each.

TABLE XVIII

COSTS PER POUND OF TDN AND DP FOR SOURCES OF ROUGHAGES APPEARING IN PROGRAMED SOLUTIONS

Activity	Cost Per Pound of Nutrient TDN	DP
	Cents	
Pasture		
Alfalfa	.8	3.4
Barley	1.2	3.7
Bermuda	.6	4.8
Bermuda-Lespedeza	1.0	5.8
Native	.9	7.8
Oats	1.6	6.2
Rye Grass	.5	4.6
Rye-Vetch	1.4	4.3
Sudan	.5	5.6
Hay		
Alfalfa	1.5	6.8
Bermuda	1.4	16.0
Bermuda-Hop Clover	1.5	16.6
Native	1.5	15.2
Rye-Vetch	1.7	5.3
Dry Grass		
Bermuda	.6	90.4
Native	.9	196.0
Concentrates		
14% Protein Dairy Feed	4.2	27.4

Pasture Activities

Pasture activities provide the mainstay of the least cost roughage systems. Of the pasture activities appearing in the programed solutions, alfalfa, barley, oats, rye grass, and rye-vetch pastures appear in solutions when no activities were denied. Alfalfa pasture, providing TDN at .8 cents per pound and DP at 3.4 cents per pound, provided nutrients in a combination at the appropriate time and at a cost that made it the most economical source of roughage in meeting the variable nutrient requirements of producing dairy cows. Alfalfa pasture appeared in every program solution when allowed to do so.

When there is no Class 1 land available, thus eliminating alfalfa pasture, native pasture is utilized which provides TDN at .9 cents per pound and DP at 7.8 cents per pound. It was found in case 2 13 03 that the 1 cent per pound TDN and 5.8 cent per pound DP provided by bermuda-lespedeza pasture was an efficient source when alfalfa, native, and oats pastures were not available.

For average producing dairy cows freshening in September, bermuda pasture appeared in the programed solution when barley, oats, and rye grass pastures were not available. Sudan pasture, providing TDN at .5 cents per pound and DP at 5.6 cents per pound, appeared in the programed solution for average producing cows only when the rest of the pasture activities listed in Table XVIII were denied. Sudan was the least economical roughage presented in Table XVIII.

Efficiency of roughage producing activities depends on more than the relative costs of the nutrients presented in Table XVIII. The distribution of the yields coupled with costs determine the opportunity costs of providing nutrients to supply alternative demands in specific months. Alfalfa, bermuda, native, and rye grass pastures produce during the summer growing season. Barley and oats pastures are efficient producers of nutrients during the winter and spring months. Rye-vetch pasture is not only a high yielding pasture during the early summer months, but produces during every month except August and September.

Hay Activities

There was not much difference in the relative efficiency of hay activities appearing in programed solutions in providing TDN. However, when hay had to provide DP, alfalfa and rye-vetch were the most efficient. Alfalfa hay provided DP at 6.8 cents per pound while rye-vetch hay cost 5.3 cents per pound of DP produced. Bermuda hay was very efficient in providing TDN and could compete with pasture activities in the summer months. Bermuda-hop clover hay was used in many cases in small quantities to supplement the pasture system.

In many programed solutions, pasture activities were very susceptible to cost instability while hay activities were seldom unstable. As the pasture activities were driven out of the solutions to gain cost stability, the roughage systems became close to dry lot operations. Dry lot type activities such as chopped green roughages were not included in the analysis. The programed results indicate that cost relationships could exist that would cause a dry lot type of roughage system to be the optimal system. However, the dry lot system was not analyzed by the study. Roughage systems with dry lot characteristics were observed only under strenuous pasture restrictions.

Dry Grass

Holding the livestock off bermuda or native pasture in the growing season and pasturing it as dry grass during the winter months was an economical way of providing TDN, especially with bermuda grass. However, it is a very low quality roughage and is probably suitable only for low quality cows and for dry cows.

Concentrates

The only grain considered by the study was a 14 per cent protein mixed dairy feed consisting of 75 per cent TDN and 11.5 per cent DP. As Table XVIII indicates, it is not as efficient in providing nutrients as the rest of the activities appearing in programed solutions when stomach capacity is not limiting. During the early months of lactation, when nutrient requirements are the highest, additional concentrate feeding above the minimum five pounds per day is usually required in order to supply adequate energy in the restrictive volume of the cow's stomach. Of the 22 programs derived for low producing dairy cows, 16 required additional feeding of concentrates during the early part of lactation. All 18 roughage programs derived for the average producing dairy cows required additional concentrate feeding during early lactation, in greater quantities, and for longer periods than with the low producing cows. Thus, the more efficient the dairy cow is in converting feed to milk, the higher the quality of the feed provided must be. This concept was also indicated in preliminary computations with high (33.2 per cent efficient) producing cows. The roughages used by the study would not, on the average, be of a sufficiently high nutrient content to enable the highly efficient cow to pack the required nutrients into the limited stomach capacity. High quality sources of nutrients such as early cut hay and concentrates would be required for the high producing cow.

Inefficient Sources of Nutrients

Several roughages considered in the study, and used by dairymen in the Oklahoma City milkshed, are inefficient. Dairymen incur unnecessary costs by including them in the roughage system. These roughages are presented in Table XIX. When the cost per pound of nutrients are compared with those in Table XVIII, some indication of the cost disadvantage is evident. The programed results indicated that these roughages did not provide a distributional opportunity cost advantage that would outweigh their initial average cost disadvantage. These roughages did not appear in any roughage system derived by the study. The small grain pastures appearing in Table XIX are activities planted only for pasture. Supplemental pasturing of wheat and other small grains planted as grain crops is known, from other studies, to be efficient.

An indication of the additional costs incurred by dairymen by including these inefficient roughages in the roughage system is given by the ZJ - CJ values presented in Appendix Table A-XX. For example, in case 1 01 03, the use of cowpea pasture would have increased costs by $13.40 per acre of cowpea pasture in the system. For replacement heifers born in September, case 3 15 09, the use of grain sorghum silage would have increased costs by $34.11 per acre of the silage produced. The other inefficient sources of nutrients presented in Table XIX have ZJ - CJ values high enough to cause them to be uneconomical sources of nutrients. The dairyman utilizing these roughages could expect to save from

TABLE XIX

COSTS PER POUND OF TDN AND DP FOR INEFFICIENT SOURCES OF ROUGHAGES NOT APPEARING IN ANY PROGRAMED SOLUTIONS

Activity	Cost Per Pound of Nutrient (Cents) TDN	DP
Pasture		
Cowpea	2.0	10.0
Vetch-Oats-Wheat	3.0	9.8
Wheat Pasture	2.7	9.4
Hay		
Cowpea	2.4	9.9
Rye Grass	2.0	22.5
Silage		
Grain Sorghum	2.4	75.1

$7.59 to $34.11 per acre of the activity used, as indicated in Appendix Table A-XX, by eliminating them from the roughage system.

The Availability of Pasture in the Programed Solutions

While pasture activities provide the mainstay of the roughage system for dairy cattle, an all-year pasture system is not always the least cost system. All cases analyzed provided pasture during the summer growing season. Cases 1 04 03, 1 02 09, 1 07 03, 2 09 03, 2 10 03, 2 13 03, and 2 14 03 were the result of denying some pasture activities which were subject to cost instability. The dairyman would probably keep some winter pasture for a holding area even when it is not included in the least cost roughage system. Therefore, the solutions for which winter pasture was not denied may be more acceptable to practical dairymen.

Average producing dairy cows freshening in April through August were not provided pasture during the winter months even when no activities were denied. If the dairyman desired winter pasture for these producing cows, it could be budgeted into the roughage system at a small increase in roughage costs. Appendix Table A-XVI contains ZJ - CJ values and ranges of linearity for winter pasture activities that could be substituted for sources of nutrients in the case solutions with net additions to total cost of less than one dollar per acre of additional winter pasture. For example, any quantity of barley pasture up to 63 acres could be substituted for other sources of nutrients in case 2 01 04 at an increase in cost of 93 cents per acre of barley used.

The roughage systems derived for replacement heifers provided pasture only during the summer growing season. This was because it was assumed that native pasture was the only source of pasture provided for replacements. If the dairyman desired winter pasture for replacement heifers, it could be budgeted into the program.

Land Use

There were no specific land requirements imposed on the roughage systems with the exception that roughage systems for March and September freshening were derived for dairymen not having any Class 1 land available. Also, replacement heifers were forced to utilize Class 3 land by denying all pasture activities except native.

Forcing the replacement heifers to use some Class 3 land was reasonable because: (1) most dairy farms in the Oklahoma City milkshed do have some Class 3 land available which is suitable only for native or unimproved pasture and hay activities; (2) of all the cases analyzed for dairy cows, only two utilized Class 3 land; and (3) in the survey conducted by Smith it was found that most farmers used native pasture for young stock and dry cows, not for producing cows.

Class 1 land is the most efficient of the three land classes in providing nutrients. In every comparison made, the absence of Class 1 land resulted in higher feed costs. In most of the cases considered, some combination of Class 1 and Class 2 land provided the least cost roughage system.

CHAPTER VI

SUMMARY

The objective of this study was to determine the least cost combination of roughages for dairy cattle in the Oklahoma City milkshed, given restrictions on nutrient requirements and stomach capacity of the animals for roughage and grain.

Cost and yield coefficients were obtained on the types of roughage available in the Oklahoma City milkshed. Nutrient requirements for low and average producing dairy cows and for replacement heifers were computed. The needs of the livestock for nutrients were related to the cost and yield data for roughages by a linear programing model in which costs of producing roughages were minimized for given animal needs. Solutions for different production situations were interpreted as to their contribution to reducing the cost of milk production and their compatibility with practices of dairymen in Oklahoma.

Many roughages in use by dairymen were found to be relatively inefficient in the sense that their use results in higher feed costs than those derived in the study. Dairymen could expect lower feed costs by eliminating cowpea, vetch-oats-wheat, and wheat activities planted only for pasture from the roughage systems. Eliminating cowpea and rye grass hay as well as grain sorghum silage would also reduce costs.

Least cost roughage systems derived by the study for producing dairy cows were characterized by: (1) grazing high yielding pastures

such as alfalfa, rye grass, and rye-vetch in the summer growing season, (2) grazing winter pasture consisting mainly of barley and oats, (3) feeding bermuda and alfalfa hay to supplement the pasture system when necessary, mainly in the winter months, and (4) substituting grain for roughage during the early months of lactation to pack more energy into the limited stomach capacity.

Low producing cows utilized some low quality roughages such as dry bermuda and native grass pasture. The nutrient requirements of the average producing cows are much higher than for the low producers, and the limited stomach capacity of the animal becomes more restrictive. The average producing dairy cows must be fed higher quality roughages and more concentrates to pack more energy into the limited stomach capacity of the dairy animal.

Replacement heifers, requiring nutrients only for growth and development, do not possess a stomach capacity limitation. Replacement heifers were restricted to native pasture to utilize the existing Class 3 land in the area and were wintered on bermuda and alfalfa hay.

Optimal roughage systems for the dairy animals considered by the study resulted in total feed costs as indicated in Table XX. The costs of optimal roughage systems for low producing cows, not considering replacements, ranged from a low of $99.79 for June freshening to a high of $108.02 for cows freshening in September. When the feed costs for replacements were included, the feed cost for the low producing cow ranged from a low of $152.54 for April freshening to a high of $160.53 per cow with replacement for September freshening. Thus, there was a possible $8.00 difference in total feed cost per low producing cow with replacement, depending on the month of freshening.

TABLE XX

TOTAL PER ANIMAL COSTS OF LEAST COST ROUGHAGE SYSTEMS FOR DAIRY ANIMALS CONSIDERED BY THE STUDY[a]

Month Of Freshening Or Birth[b]	Animal Unit				
	Low Producing Cows		Average Producing Cows		
	With Replacements	Without Replacements	With Replacements	Without Replacements	Replacement Heifers
Jan	$154.37	$104.34	$190.46	$140.44	$84.47
Feb	153.33	103.79	196.65	147.11	86.77
Mar	155.14	105.14	202.56	152.56	89.26
Apr	152.54	101.81	198.83	158.15	89.56
May	155.02	102.96	199.80	147.74	89.81
Jun	153.35	99.79	206.47	152.91	87.51
Jul	154.49	100.75	206.19	152.45	88.36
Aug	157.22	103.33	205.26	151.37	88.51
Sep	160.53	108.02	209.07	156.56	88.74
Oct	156.90	103.88	213.31	160.27	83.37
Nov	157.36	104.25	208.17	155.06	82.56
Dec	157.56	104.32	203.30	150.06	83.34

[a]This data represents the annual feed costs for the dairy cows and the cost for their replacements from birth to 24 months of age.

[b]The month represents date of freshening for cows and date of birth for heifers.

A possible difference of approximately $23.00, depending on the month of freshening, existed in the total feed costs for the average producing cow with replacement. The highest feed cost for average producing cows with replacements resulted from October freshening. The lowest total feed cost for the average producing dairy cow with replacement occurred when the cow freshened in February, with a total feed cost of $196.65. When the cost of feeding the average producing cow's replacement was not considered, the highest feed cost, $160.27, resulted from October freshening. The lowest total feed costs, not considering replacements, occurred with the average producing cow freshening in January with a total feed cost of $140.44.

Total feed cost of raising dairy replacement heifers as indicated in Table XX ranged from a low of $82.56 for the heifer born in November to a high of $89.81 for the replacement heifer born in May. This represented a possible deviation of total feed costs for replacement heifers of $7.25, depending on the month of birth.

Dairymen can study the proposed roughage systems for ideas about cutting costs of feeding dairy cattle while insuring adequate availability of nutrients. Dairymen must compare nutrient requirements, yields, and costs for their own farm with those assumed in the study before deciding to change from their present roughage system to one of the systems proposed in the study.

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APPENDIX A

APPENDIX TABLE A-I

MONTHLY TDN REQUIREMENTS FOR A 1,300 POUND DAIRY COW PRODUCING 8,000 POUNDS OF MILK PER YEAR[a]

	Month of Calving											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	557	466	488	374	374	374	405	435	466	496	527	557
Feb	557	557	466	488	374	374	374	405	435	466	496	527
Mar	527	557	557	466	488	374	374	374	405	435	466	496
Apr	496	527	557	557	466	488	374	374	374	405	435	466
May	466	496	527	557	557	466	488	374	374	374	405	435
Jun	435	466	496	527	557	557	466	488	374	374	374	405
Jul	405	435	466	496	527	557	557	466	488	374	374	374
Aug	374	405	435	466	496	527	557	557	466	488	374	374
Sep	374	374	405	435	466	496	527	557	557	466	488	374
Oct	374	374	374	405	435	466	496	527	557	557	466	488
Nov	488	374	374	374	405	435	466	496	527	557	557	466
Dec	466	488	374	374	374	405	435	466	496	527	557	557

[a]In addition to these requirements, five pounds of 14% protein prepared dairy feed are fed daily except during the first dry month. For total nutrient requirements, see Table IV, p. 20.

APPENDIX TABLE A-II

MONTHLY TDN REQUIREMENTS FOR A 1,300 POUND DAIRY COW PRODUCING 11,000 POUNDS OF MILK PER YEAR[a]

	Month of Calving											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	801	618	488	374	374	435	496	557	618	679	740	801
Feb	801	801	618	488	374	374	435	496	557	618	679	740
Mar	740	801	801	618	488	374	374	435	496	557	618	679
Apr	679	740	801	801	618	488	374	374	435	496	557	618
May	618	679	740	801	801	618	488	374	374	435	496	557
Jun	557	618	679	740	801	801	618	488	374	374	435	496
Jul	496	557	618	679	740	801	801	618	488	374	374	435
Aug	435	496	557	618	679	740	801	801	618	488	374	374
Sep	374	435	496	557	618	679	740	801	801	618	488	374
Oct	374	374	435	496	557	618	679	740	801	801	618	488
Nov	488	374	374	435	496	557	618	679	740	801	801	618
Dec	618	488	374	374	435	496	557	618	679	740	801	801

[a]In addition to these requirements, five pounds of 14% protein prepared dairy feed are fed daily except during the first dry month. For total nutrient requirements, see Table IV, p. 20.

APPENDIX TABLE A-III

MONTHLY DP REQUIREMENTS FOR A 1,300 POUND DAIRY COW
PRODUCING 8,000 POUNDS OF MILK PER YEAR[a]

	Month of Calving											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	62	34	43	31	33	34	39	43	48	52	57	62
Feb	62	62	34	43	31	33	34	39	43	48	52	57
Mar	57	62	62	34	43	31	33	34	39	43	48	52
Apr	52	57	62	62	34	43	31	33	34	39	43	48
May	48	52	57	62	62	34	43	31	33	34	39	43
Jun	43	48	52	57	62	62	34	43	31	33	34	39
Jul	39	43	48	52	57	62	62	34	43	31	33	34
Aug	34	39	43	48	52	57	62	62	34	43	31	33
Sep	33	34	39	43	48	52	57	62	62	34	43	31
Oct	31	33	34	39	43	48	52	57	62	62	34	43
Nov	42	31	33	34	39	43	48	52	57	62	62	34
Dec	34	43	31	33	34	39	43	48	52	57	62	62

[a]In addition to these requirements, five pounds of 14% protein prepared dairy feed are fed daily except during the first dry month. For total nutrient requirements, see Table IV, p. 20.

APPENDIX TABLE A-IV

MONTHLY DP REQUIREMENTS FOR A 1,300 POUND DAIRY COW PRODUCING 11,000 POUNDS OF MILK PER YEAR[a]

	Month of Calving											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	100	49	43	31	35	44	53	65	72	81	91	100
Feb	100	100	49	43	31	35	44	53	65	72	81	91
Mar	91	100	100	49	43	31	35	44	53	65	72	81
Apr	81	91	100	100	49	43	31	35	44	53	65	72
May	72	81	91	100	100	49	43	31	35	44	53	65
Jun	65	72	81	91	100	100	49	43	31	35	44	53
Jul	53	65	72	81	91	100	100	49	43	31	35	44
Aug	44	53	65	72	81	91	100	100	49	43	31	35
Sep	35	44	53	65	72	81	91	100	100	49	43	31
Oct	31	35	44	53	65	72	81	91	100	100	49	43
Nov	43	31	35	44	53	65	72	81	91	100	100	49
Dec	49	43	31	35	44	53	65	72	81	91	100	100

[a]In addition to these requirements, five pounds of 14% protein prepared dairy feed are fed daily except during the first dry month. For total nutrient requirements, see Table IV, p. 20.

APPENDIX TABLE A-V

MONTHLY TDN PASTURE REQUIREMENTS FOR A DAIRY REPLACEMENT HEIFER FROM BIRTH TO 24 MONTHS OF AGE[a]

	Month of Birth											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	305	663	646	627	605	583	561	538	512	326	320	314
Feb	314	305	663	646	627	605	583	561	538	512	326	320
Mar	320	314	305	663	646	627	605	583	561	538	512	326
Apr	326	320	314	305	663	646	627	605	583	561	538	512
May	512	326	320	314	305	663	646	627	605	583	561	538
Jun	538	512	326	320	314	305	663	646	627	605	583	561
Jul	561	538	512	326	320	324	305	663	646	627	605	583
Aug	583	561	538	512	326	320	314	305	663	646	627	605
Sep	605	583	561	538	512	326	320	314	305	663	646	627
Oct	627	605	583	561	538	512	326	320	314	305	663	646
Nov	646	627	605	583	561	538	512	326	320	314	305	663
Dec	663	646	627	605	583	561	538	512	326	320	314	305

[a]Requirements for the first four months of life are not included in this table. For total nutrient requirements, see Table V, p. 24.

APPENDIX TABLE A-VI

MONTHLY DP PASTURE REQUIREMENTS FOR A DAIRY REPLACEMENT HEIFER FROM BIRTH TO 24 MONTHS OF AGE[a]

	Month of Birth											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	30	61	62	61	61	59	58	57	56	30	30	30
Feb	30	30	61	62	61	61	59	58	57	56	30	30
Mar	30	30	30	61	62	61	61	59	58	57	56	30
Apr	30	30	30	30	61	62	61	61	59	58	57	56
May	56	30	30	30	30	61	62	61	61	59	58	57
Jun	57	56	30	30	30	30	61	62	61	61	59	58
Jul	58	57	56	30	30	30	30	61	62	61	61	59
Aug	59	58	57	56	30	30	30	30	61	62	61	61
Sep	61	59	58	57	56	30	30	30	30	61	62	61
Oct	61	61	59	58	57	56	30	30	30	30	61	62
Nov	62	61	61	59	58	57	56	30	30	30	30	61
Dec	61	62	61	61	59	58	57	56	30	30	30	30

[a]Requirements for the first four months of life are not included in this table. For total nutrient requirements, see Table V, p. 24.

APPENDIX TABLE A-VII

DRY MATTER AND DIGESTIBLE NUTRIENT CONTENT OF FEEDING STUFF CONSIDERED BY THE STUDY[a]

Feeding Stuff	Total Dry Matter Per Cent	Digestible Protein Per Cent	Total Digestible Nutrients Per Cent	Ratio of Total Dry Matter To TDN (Conversion Factor)	Ratio of DP To TDN (Conversion Factor)
Concentrates					
14% Protein Dairy Feed	88.1	11.5	75.0	1.175	.153
Hay					
Alfalfa	90.5	10.9	50.7	1.785	.215
Bermuda	90.5	3.6	44.2	2.048	.081
Bermuda-Hop Clover	88.0	4.5	49.7	1.771	.091
Cowpea	90.4	12.3	51.4	1.759	.239
Johnson Grass	90.2	2.9	50.3	1.793	.058
Millet	87.6	4.9	50.0	1.752	.099
Native	91.3	2.0	45.1	2.024	.044
Rye Grass	88.0	4.7	52.5	1.676	.090
Rye-Vetch	88.0	9.9	54.8	1.606	.181
Sudan	89.4	4.3	48.6	1.840	.088
Pasture					
Alfalfa	24.4	3.5	14.8	1.649	.236
Barley	20.0	3.9	12.5	1.600	.312
Bermuda	25.0	2.0	15.0	1.667	.133
Bermuda-Lespedeza	25.0	2.5	14.6	1.712	.171
Cowpea	16.3	2.2	10.8	1.509	.204
Johnson Grass	25.0	2.5	15.6	1.603	.160
Millet	25.9	1.8	18.7	1.385	.096

(Continued)

APPENDIX TABLE A-VII (Continued)

Feeding Stuff	Total Dry Matter Per Cent	Digestible Protein Per Cent	Total Digestible Nutrients Per Cent	Ratio of Total Dry Matter To TDN (Conversion Factor)	Ratio of DP To TDN (Conversion Factor)
Pasture					
Native	35.0	2.3	21.0	1.667	.110
Oat	14.1	2.4	9.2	1.533	.261
Oats-Vetch	25.0	4.1	14.8	1.689	.277
Rye Grass	26.6	1.9	18.0	1.478	.106
Rye-Vetch	27.0	5.1	15.8	1.709	.323
Sudan	21.6	2.4	14.3	1.510	.084
Vetch-Oats-Wheat	27.0	5.1	16.4	1.646	.311
Wheat	19.8	3.6	12.7	1.559	.283
Dry Grass					
Dry Bermuda	90.0	.2	29.5	3.051	.007
Dry Native	90.0	.2	41.3	2.179	.005
Silage					
Grain Sorghum	33.4	1.0	18.7	1.786	.053

[a]Source: See F. B. Morrison, Feeds and Feeding. (Ithaca, New York, 1951), p. 1,000.

APPENDIX TABLE A-VIII

DISTRIBUTION OF PASTURE YIELDS (TDN) FOR SELECTED TYPES OF PASTURE, CENTRAL OKLAHOMA[a]

Type Pasture	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa	-	-	64	221	271	271	271	274	200	237	60	-
Barley	242	301	382	44	264	-	-	-	-	-	-	125
Bermuda	-	-	57	125	125	85	125	51	-	-	-	-
Bermuda-Lespedeza	-	-	-	80	180	260	241	151	148	115	29	-
Cowpea	-	-	-	-	-	111	273	143	162	174	8	-
Johnson Grass	-	-	24	128	189	189	189	208	307	242	14	-
Millet	-	-	-	-	-	103	255	133	151	162	7	-
Native	-	-	-	21	115	130	107	91	117	102	1	-
Oat	151	188	238	275	165	-	-	-	-	-	22	57
Oats-Vetch	26	42	80	196	225	135	11	-	-	26	77	50
Rye Grass	-	-	-	-	-	233	574	299	341	366	17	-
Rye-Vetch	43	69	129	318	365	219	17	-	-	43	124	82
Sudan	-	-	-	-	-	150	370	193	220	236	11	-
Vetch-Oats-Wheat	20	33	62	153	176	105	8	-	-	21	60	39
Wheat	92	131	167	192	115	-	-	-	-	-	15	54

[a]Source: See F. J. Smith, "A Linear Program Analysis of Roughage Systems for Grade A Dairy Farms in Grady and Lincoln Counties" (unpublished Master of Science thesis, Oklahoma State University, 1962), p. 106. For annual totals, see Table VI, page 25.

APPENDIX TABLE A-IX

DISTRIBUTION OF PASTURE YIELDS (DP) FOR SELECTED TYPES OF PASTURE, CENTRAL OKLAHOMA

	Month											
Type Pasture	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa	-	-	15.1	52.3	64.1	64.1	64.1	64.8	47.3	56.0	14.2	-
Barley	31.1	38.7	49.2	5.7	34.0	-	-	-	-	-	-	16.1
Bermuda	-	-	7.6	16.7	16.7	11.3	16.7	6.8	-	-	-	-
Bermuda-Lespedeza	-	-	-	13.7	30.8	44.5	41.3	25.9	25.3	19.7	5.0	-
Cowpea	-	-	-	-	-	23.6	56.6	29.1	33.0	35.4	1.6	-
Johnson Grass	-	-	1.4	7.4	11.0	11.0	11.0	12.1	17.8	14.0	.8	-
Millet	-	-	-	-	-	9.9	24.5	12.8	14.5	15.6	.7	-
Native	-	-	-	2.0	12.0	13.0	11.0	9.0	12.0	10.0	-	-
Oat	39.4	49.0	62.1	71.7	43.0	-	-	-	-	-	5.7	14.9
Oats-Vetch	7.2	11.6	22.2	54.3	62.3	37.4	3.0	-	-	7.2	21.3	13.9
Rye Grass	-	-	-	-	-	24.6	60.6	31.6	36.0	38.6	1.8	-
Rye-Vetch	13.4	21.6	40.3	99.4	114.1	68.4	5.3	-	-	13.4	38.8	25.6
Sudan	-	-	-	-	-	25.2	62.1	32.4	36.9	39.6	1.8	-
Vetch-Oats-Wheat	5.4	9.1	17.2	42.4	48.8	29.1	2.2	-	-	2.2	16.6	10.8
Wheat	11.6	11.6	21.1	24.3	14.5	-	-	-	-	-	2.0	6.8

APPENDIX TABLE A-X

DISTRIBUTION OF PASTURE YIELDS (DRY MATTER) FOR SELECTED TYPES OF PASTURE, CENTRAL OKLAHOMA

	Month											
Type Pasture	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alfalfa	-	-	106	364	447	447	447	452	330	391	99	-
Barley	387	482	611	70	422	-	-	-	-	-	-	-
Bermuda	-	-	95	208	208	142	308	85	-	-	-	-
Bermuda-Lespedeza	-	-	-	137	308	445	413	259	253	197	50	-
Cowpea	-	-	-	-	-	168	412	216	244	263	12	-
Johnson Grass	-	-	38	205	303	303	303	333	492	388	22	-
Millet	-	-	-	-	-	143	353	184	209	224	10	-
Native	-	-	-	35	192	217	178	152	195	170	2	-
Oat	231	288	365	421	253	-	-	-	-	-	34	87
Oats-Vetch	44	71	135	331	380	228	19	-	-	44	130	84
Rye Grass	-	-	-	-	-	357	880	458	523	561	26	-
Rye-Vetch	73	118	219	543	624	374	29	-	-	73	212	140
Sudan	-	-	-	-	-	230	567	296	337	362	17	-
Vetch-Oats-Wheat	33	54	102	252	290	173	13	-	-	35	99	64
Wheat	143	204	260	299	179	-	-	-	-	-	23	84

APPENDIX TABLE A-XI

IDENTIFICATION OF ACTIVITIES USED IN THE STUDY, OKLAHOMA CITY MILKSHED

Activity	Units	Process Number
Hay[a]	Acre	
Alfalfa		1-12
Bermuda		13-24
Bermuda-Hop Clover		25-36
Cowpea		37-48
Johnson Grass		49-60
Millet		61-72
Native		73-84
Rye Grass		85-96
Rye-Vetch		97-108
Sudan		109-120
Pasture	Acre	
Alfalfa		121
Barley		122
Bermuda		123
Bermuda-Lespedeza		124
Cowpea		125
Johnson Grass		126
Millet		127
Native		128
Oat		129
Oats-Vetch		130
Rye Grass		131
Rye-Vetch		132
Sudan		133
Vetch-Oats-Wheat		134
Wheat		135
Dry Grass[b]	Acre	
Bermuda		136-141
Native		142-146
Concentrates	Cwt.	
14% Protein Dairy Feed		147-158
Silage[a]	Acre	
Grain Sorghum		159-170
Excess Digestible Protein	Pound	171-182

(Footnotes Continued)

APPENDIX TABLE A-XI (Continued)

[a]Hay and silage activities command 12 processes; one process for each month of the year. The first process under a hay (silage) activity is producing hay (silage) to be fed in January, while the last or twelfth process listed under a hay (silage) activity is producing hay (silage) to be fed in December.

[b]Dry grass activities command a process for each month in which the grass does not produce. The first process entered under a dry grass activity is producing grass to be grazed as dry grass during the first month of the year in which there is no production. For example, process number 135 is producing bermuda grass to be pastured as dry grass in January. Similarly, the last process entered under a dry grass activity is producing grass to be pastured as dry grass during the last month of the year in which there is no production of that grass.

APPENDIX TABLE A-XII

CASE NUMBER IDENTIFICATION CODE

Identification Code (Six Digit)[a]					
Digit					
1		2 and 3		4 and 5	
Animal Class	Code	Situation (Processes Denied)	Code	Month of Calving	Code
Dairy Cows Producing 8,000 lbs. Milk Per Year	1	None	01	Jan	01
		136-146	02	Feb	02
		121, 122, 129 and 136-146	03		
		122, 128, 129, 131, 132 and 136-146	04	Mar	03
		1-12, 121 and 136-146	05	Apr	04
		1-12, 121, 128, 129 and 136-146	06	May	05
Dairy Cows Producing 11,000 lbs. Milk Per Year	2	1-12, 121, 122, 128, 129, 132 and 136-146	07	Jun	06
		1-12, 121, 128, 129, 132 and 136-146	08	Jul	07
		97-108, 122, 129 and 132	09	Aug	08
		97-108, 122, 123, 129 and 132	10	Sep	09
		25-36, 121 and 122	11		
		1-12 and 121	12	Oct	10
Dairy Replacement Heifers From Birth to 24 Months	3	1-12, 121, 122, 128 and 129	13	Nov	11
		1-12, 121, 122, 124, 128, 129 and 131	14	Dec	12
		All Pasture except Native	15		

[a]For example, dairy replacement heifers born in March and denied all pasture except native have the case number 3 15 03.

APPENDIX TABLE A-XIII

ROUGHAGES IN USE BY DAIRYMEN AND THEIR USE BY THE STUDY, OKLAHOMA CITY MILKSHED

Roughages in Use By Dairymen[a]	Analyzed By the Study For: Low Producing Dairy Cows	Average Producing Dairy Cows	Replacement Heifers	Appearing In Program Solutions
Hay				
Alfalfa	X	X	X	X
Barley				
Bermuda	X	X	X	X
Bermuda-Hop Clover	X	X	X	X
Bermuda-Lespedeza				
Cowpea			X	
Johnson Grass				
Lespedeza				
Millet			X	
Native	X		X	X
Oat				
Oats-Barley-Rye				
Oats-Rye				
Oats-Vetch				
Rye Grass			X	
Rye-Barley				
Rye-Vetch		X	X	X
Sudan			X	
Vetch-Oats-Barley				
Vetch-Oats-Wheat				
Pasture				
Alfalfa	X	X	X	X
Barley	X	X	X	X
Bermuda	X	X	X	X
Bermuda-Lespedeza	X	X	X	X
Cowpea	X	X	X	
Johnson Grass				
Lespedeza				
Millet				
Native	X	X	X	X
Oat		X		
Oats-Barley-Rye				
Oats-Rye				
Oats-Vetch				
Rye Grass	X	X	X	X
Rye				
Rye-Barley				
Rye-Vetch	X	X	X	X

(Continued)

APPENDIX TABLE A-XIII (Continued)

Roughage in Use By Dairymen[a]	Analyzed By the Study For Low Producing Dairy Cows	Average Producing Dairy Cows	Replacement Heifers	Appearing In Program Solutions
Pasture				
Sudan		X		
Sorghum (Sweet)				
Vetch				
Vetch-Oats-Barley				
Vetch-Oats-Wheat	X	X	X	
Wheat	X		X	
Dry Grass				
Bermuda	X			X
Native	X			X
Silage				
Alfalfa				
Barley				
Bermuda				
Johnson Grass				
Hegeri				
Oat				
Oats-Barley-Rye				
Oats-Rye				
Rye				
Rye-Barley				
Rye-Vetch				
Sudan				
Sorghum (Sweet)				
Sorghum (Grain)			X	
Vetch-Oats-Barley				
Vetch-Oats-Wheat				

[a]Source: See F. J. Smith, "A Linear Program Analysis of Roughage Systems For Grade A Dairy Farms in Grady and Lincoln Counties" (unpublished Master of Science thesis, Oklahoma State University, 1962), p. 28.

APPENDIX TABLE A-XIV

SHADOW PRICES OF UNSTABLE PROCESSES IN PROGRAMED SOLUTIONS FOR LOW PRODUCING DAIRY COWS

Case Number	Process Number	Cost Per Acre	Acres	Shadow Prices[a] Upper Bound	Entering Process	Lower Bound	Entering Process
1 01 01	132	$19.29	33	$19.50	18	$16.48	20
1 01 02	132	19.29	25	19.98	11	18.41	181
1 01 03	129	17.62	64	17.77	2	15.84	171
	131	9.00	2	9.39	2	7.02	17
1 01 04	129	17.62	40	18.35	150	17.12	4
	132	19.29	8	19.48	29	17.48	150
1 01 05	132	19.29	14	20.11	29	17.48	20
1 01 10	144	5.88	51	6.29	132	17.40	131
1 01 11	132	19.29	2	19.50	18	16.48	20
1 01 12	132	19.29	17	19.50	18	16.48	20
1 02 03	121	14.66	158	15.54	131	None	None
	122	20.27	11	20.56	17	19.28	131
	129	17.62	43	18.55	150	17.38	4
1 03 03	5	51.03	.1	51.90	29	49.80	29
	128	5.88	146	6.23	22	5.77	18
	131	9.00	51	9.74	18	7.00	22
	132	19.29	85	19.40	18	18.43	22
1 05 03	128	5.88	228	6.24	132	4.88	19
	129	17.62	88	18.42	150	17.09	16
1 06 03	122	20.27	101	20.56	149	19.30	15
	132	19.29	71	19.46	17	18.90	149
1 05 09	128	5.88	71	6.03	73	5.38	84
	129	17.62	14	17.81	73	15.53	170
1 06 09	132	19.29	83	19.71	18	3.80	19

[a]See page 42 for a discussion of the use of shadow prices.

APPENDIX TABLE A-XV

SHADOW PRICES OF UNSTABLE PROCESSES IN PROGRAMED SOLUTIONS FOR AVERAGE PRODUCING DAIRY COWS

Case Number	Process Number	Cost Per Acre	Acres	Shadow Prices[a] Upper Bound	Entering Process	Lower Bound	Entering Process
2 01 01	121	$14.66	119	$15.04	129	$13.76	1
	122	20.27	112	21.15	1	18.91	XX[b]
2 01 02	121	14.66	131	15.47	101	13.17	99
	122	20.27	82	20.74	2	18.72	XX[c]
	129	17.62	51	18.17	99	17.36	2
2 01 03	101	39.49	3	40.09	152	37.78	99
	102	39.49	14	40.42	152	24.26	XX[d]
	121	14.66	64	15.13	30	14.60	152
	122	20.27	44	20.44	99	20.11	152
	129	17.62	140	17.68	152	17.15	30
	131	9.00	77	9.09	152	8.27	30
2 01 04	31	43.28	1	43.92	7	39.97	149
	121	14.66	120	14.84	7	14.55	102
	131	9.00	58	9.17	102	8.73	7
2 01 05	121	14.66	159	15.06	101	-1.70	102
2 01 06	121	14.66	12	22.33	102	14.15	170
2 01 07	34	43.28	5	44.02	10	35.35	156
2 01 10	121	14.66	109	15.28	36	10.51	158
	122	20.27	52	24.31	158	19.67	36

(Continued)

APPENDIX TABLE A-XV (Continued)

Case Number	Process Number	Cost Per Acre	Acres	Shadow Prices[a] Upper Bound	Entering Process	Lower Bound	Entering Process
2 01 11	121	$14.66	84	$14.86	36	$10.09	158
	122	20.27	101	24.72	158	20.08	36
	131	9.00	25	17.33	133	8.58	36
2 01 12	121	14.66	107	14.81	36	10.04	158
	122	20.27	101	24.77	158	20.13	36
	131	9.00	25	17.32	133	8.69	36
2 09 03	123	9.04	45	9.05	29	18.72	99
2 12 03	122	20.27	31	20.44	99	18.72	100
	128	5.88	188	6.13	22	4.58	19
	129	17.62	185	18.50	100	16.67	99
2 13 03	124	12.02	36	12.14	105	11.99	178
	131	9.00	92	9.10	178	8.56	105

[a]See page 42 for a discussion of the use of shadow prices.

[b]The entering process was excess stomach capacity in January.

[c]The entering process was excess stomach capacity in February.

[d]The entering process was excess stomach capacity in July.

APPENDIX TABLE A-XVI

SELECTED ZJ - CJ VALUES FROM PROGRAMED ACTIVITIES NOT APPEARING IN CASE SOLUTIONS

Case Number	Activity	ZJ - CJ Value[a]	Upper Limit
1 01 01	Native Pasture	$ .84	160
1 01 02	Native Pasture	.80	6
	Bermuda-Hop Clover Hay-April	.88	2
1 01 04	14% Protein Dairy Feed-April	.85	28
1 01 09	Native Pasture	.99	153
1 01 11	Native Pasture	.84	11
1 01 12	Native Pasture	.84	10
1 02 09	Barley Pasture	1.80	30
1 04 03	Bermuda Pasture	.76	5
1 05 03	Rye-Vetch Pasture	.34	25
1 05 09	Barley Pasture	.86	37
	Native Hay-January	.25	4
1 06 09	Barley Pasture	.91	8
2 01 01	Oats Pasture	.17	63
2 01 02	Alfalfa Hay-February	.91	13
2 01 04	Barley Pasture	.92	63
	Oats Pasture	.23	37
2 01 05	Barley Pasture	1.09	21
	Oats Pasture	1.86	36
	Rye-Vetch Pasture	1.87	41
2 01 06	Rye-Vetch Pasture	.83	61
2 01 07	Rye-Vetch Pasture	.69	69
2 01 08	Native Pasture	.95	25
	Rye-Vetch Pasture	.87	2
2 01 11	Bermuda-Hop Clover Hay-December	.33	19
2 01 12	Bermuda-Hop Clover Hay-December	.24	19
	Native Pasture	.91	200
2 09 03	Bermuda-Hop Clover Hay-May	.01	2
	Rye-Vetch Pasture	.57	17
2 10 03	Rye-Vetch Pasture	.57	17
2 11 09	Native Pasture	.25	203
2 14 03	Rye-Vetch Pasture	.17	8

[a]For interpretation of ZJ - CJ values see page 29.

APPENDIX TABLE A-XVII

DISTRIBUTION OF HAY AND GRAIN FEEDING FOR LOW PRODUCING DAIRY COW SOLUTIONS, TONS PER ACTIVITY PER MONTH

Case Number	Hay or Grain Activity	Total Tons	Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 01 01	Alfalfa	108	26.6	25.2	40.2	-	-	-	-	-	-	-	4.9	11.2
	Bermuda	14	-	-	-	13.6	.9	-	-	-	-	-	-	-
1 01 02	Alfalfa	108	13.6	26.2	43.8	8.4	-	-	-	-	-	-	-	16.4
	Bermuda	14	-	-	-	7.5	4.4	2.2	-	-	-	-	-	-
1 01 03	Alfalfa	20	7.4	-	-	.7	-	-	-	-	-	-	2.8	9.4
	Bermuda	16	-	-	-	3.5	-	8.4	4.0	.4	-	-	-	-
	Bermuda-Hop Clover	31	-	-	31.0	-	-	-	-	-	-	-	-	-
	14% Protein Feed	1	-	-	1.2	-	-	-	-	-	-	-	-	-
1 01 04	Alfalfa	32	6.0	-	-	-	-	-	-	-	-	-	14.4	11.2
	Bermuda	10	-	-	-	-	-	5.7	4.0	.4	-	-	-	-
	Bermuda-Hop Clover	12	-	-	-	5.3	-	4.0	2.8	.3	-	-	-	-
	14% Protein Feed	-	-	-	-	-	.3	-	-	-	-	-	-	-
1 01 05	Alfalfa	77	14.0	12.6	35.4	-	-	-	-	-	-	-	.7	14.0
	Bermuda	7	-	-	-	2.6	-	-	4.0	-	-	-	-	-
	Bermuda-Hop Clover	2	-	-	-	-	-	2.2	-	-	-	-	-	-
	14% Protein Feed	2	-	-	-	-	1.1	1.1	-	-	-	-	-	-
1 01 06	Alfalfa	59	15.4	15.1	2.4	-	-	-	-	-	-	-	8.1	17.8
	Bermuda	14	-	-	-	12.8	-	-	.9	-	-	-	-	-
	Bermuda-Hop Clover	5	-	-	-	4.6	-	-	-	-	-	-	-	-
	14% Protein Feed	1	-	-	-	-	-	.7	-	-	-	-	-	-
1 01 07	Alfalfa	93	17.8	15.4	28.0	-	-	-	-	-	-	-	11.9	20.0
	Bermuda	15	-	-	-	5.3	9.7	-	-	-	-	-	-	-
	Bermuda-Hop Clover	7	-	-	-	-	-	-	-	6.8	-	-	-	-
	14% Protein Feed	-	-	-	-	-	-	-	-	.4	-	-	-	-

(Continued)

APPENDIX TABLE A-XVII (Continued)

Case Number	Hay or Grain Activity	Total Tons	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 01 08	Alfalfa	107	20.0	17.8	32.6	-	-	-	-	-	-	-	14.3	22.0
	Bermuda	17	-	-	-	7.9	8.8	-	-	-	-	-	-	-
	Bermuda-Hop Clover	12	-	-	-	-	-	-	-	12.4	-	-	-	-
	14% Protein Feed	-	-	-	-	-	-	-	-	-	-	-	-	-
1 01 09	Alfalfa	101	22.0	18.9	34.6	-	-	-	-	-	-	-	.7	24.5
	Bermuda	32	-	-	-	15.4	9.2	-	-	7.9	-	-	-	-
	Bermuda-Hop Clover	88	-	-	-	-	-	-	-	-	22.6	18.0	47.1	-
	14% Protein Feed	1	-	-	-	-	-	-	-	-	-	.7	-	-
1 01 10	Alfalfa	126	24.2	22.0	34.6	-	-	-	-	-	-	-	19.2	26.2
	Bermuda	25	-	-	-	11.9	-	-	-	12.8	-	-	-	-
1 01 11	Alfalfa	135	26.2	23.8	37.4	-	-	-	-	-	-	-	19.2	28.4
	Bermuda	18	-	-	-	15.0	3.5	-	-	-	-	-	-	-
1 01 12	Alfalfa	121	27.6	24.8	38.8	-	-	-	-	-	-	-	2.8	26.6
	Bermuda	14	-	-	-	13.2	.9	-	-	-	-	-	-	-
1 02 03	Bermuda	181	46.2	40.9	-	-	-	7.9	4.4	.4	10.6	-	31.2	39.2
	Bermuda-Hop Clover	41	-	-	31.3	9.3	-	-	-	-	-	-	-	-
	14% Protein Feed	2	-	-	1.7	-	-	-	-	-	-	-	-	-
1 03 03	Alfalfa	-	-	-	-	-	.4	-	-	-	-	-	-	-
	Bermuda	195	52.4	47.5	-	-	5.3	-	-	17.2	7.0	-	30.4	35.2
	Bermuda-Hop Clover	64	-	-	42.2	22.0	-	-	-	-	-	-	-	-
	14% Protein Feed	8	-	-	3.9	3.6	-	-	-	-	-	-	-	-
1 04 03	Bermuda	152	41.4	-	11.4	-	-	7.9	4.4	.4	10.6	-	32.6	43.6
	Bermuda-Hop Clover	63	-	-	43.4	19.5	-	-	-	-	-	-	-	-
	Native	13	13.1	-	-	-	-	-	-	-	-	-	-	-
	14% Protein Feed	6	-	-	3.6	1.9	-	-	-	-	-	-	-	-

(Continued)

APPENDIX TABLE A-XVII (Continued)

Case Number	Hay or Grain Activity	Total Tons	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 02 09	Alfalfa	22	7.4	5.2	-	-	-	-	-	-	-	-	-	9.1
	Bermuda	224	45.8	44.4	39.2	15.4	9.2	-	-	7.9	-	-	14.5	47.1
	Bermuda-Hop Clover	78	-	-	-	-	-	-	-	-	22.6	18.0	36.9	-
	14% Protein Feed	2	-	-	-	-	-	-	-	-	1.0	.7	-	-
1 05 03	Bermuda	170	34.8	26.8	-	-	7.0	12.8	-	13.2	.9	-	40.5	34.3
	Bermuda-Hop Clover	56	-	-	28.2	27.9	-	-	-	-	-	-	-	-
1 06 03	Bermuda	155	24.6	13.2	-	-	-	18.0	-	23.3	15.8	6.2	31.7	22.0
	Bermuda-Hop Clover	34	-	-	8.7	25.4	-	-	-	-	-	-	-	-
	14% Protein Feed	3	-	-	-	3.4	-	-	-	-	-	-	-	-
1 07 03	Bermuda	152	-	3.1	36.1	36.1	34.8	11.9	-	24.6	1.8	3.1	-	-
	Bermuda-Hop Clover	64	-	-	-	-	-	-	-	-	27.3	23.6	13.3	-
	Native	154	43.0	40.0	-	-	-	-	-	-	-	28.4	42.3	-
	14% Protein Feed	76	1.8	-	16.5	16.5	17.3	13.1	-	-	-	-	6.8	4.3
1 05 09	Bermuda	230	-	48.8	43.1	35.2	17.6	8.4	-	22.4	-	1.3	1.8	51.5
	Bermuda-Hop Clover	82	-	-	-	-	-	-	-	-	14.3	21.1	46.5	-
	14% Protein Feed	8	-	-	-	-	-	-	-	-	7.7	-	-	-
1 06 09	Bermuda	225	-	43.6	44.0	34.8	12.8	8.4	-	25.5	1.3	3.1	1.8	49.7
	Bermuda-Hop Clover	77	-	-	-	-	-	-	-	-	13.3	21.1	42.8	-
	14% Protein Feed	10	-	-	-	-	-	-	-	-	9.6	-	-	-
1 08 09	Bermuda	170	30.8	21.6	10.1	39.2	18.0	20.7	-	24.6	1.8	3.1	-	-
	Bermuda-Hop Clover	52	-	-	-	-	-	-	-	-	14.9	23.6	13.3	-
	Native	66	-	-	-	-	-	-	-	-	-	-	28.4	37.7
	14% Protein Feed	15	-	-	-	-	-	-	-	-	7.7	-	6.8	.6

APPENDIX TABLE A-XVIII

DISTRIBUTION OF HAY AND GRAIN FEEDING FOR AVERAGE PRODUCING DAIRY COW SOLUTIONS, TONS PER ACTIVITY PER MONTH

Case Number	Hay or Grain Activity	Total Tons	Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2 01 01	Bermuda	207	37.4	32.6	-	-	-	20.7	3.5	4.0	5.7	-	48.0	55.4
	Rye-Vetch	46	20.2	17.7	8.1	-	-	-	-	-	-	-	-	-
	14% Protein Feed	12	-	-	10.2	1.7	-	-	-	-	-	-	-	-
2 01 02	Bermuda	212	39.6	37.0	-	-	-	26.0	11.9	10.1	13.2	-	32.6	41.4
	Rye-Vetch	26	-	13.6	-	12.0	-	-	-	-	-	-	-	-
	14% Protein Feed	30	-	-	18.8	10.2	1.5	-	-	-	-	-	-	-
2 01 03	Bermuda	137	19.8	26.0	-	-	-	-	-	17.6	12.3	-	33.9	27.7
	Rye-Vetch	40	-	-	-	-	8.1	31.5	-	-	-	-	-	-
	14% Protein Feed	43	-	-	17.2	17.1	9.1	-	-	-	-	-	-	-
2 01 04	Alfalfa	4	-	-	-	-	-	-	-	-	-	-	-	3.5
	Bermuda	253	43.6	51.5	62.9	-	-	-	-	13.6	-	-	40.9	40.0
	Bermuda-Hop Clover	3	-	-	-	-	-	-	3.1	-	-	-	-	-
	Rye-Vetch	55	-	4.6	-	22.3	16.1	12.0	-	-	-	-	-	-
	14% Protein Feed	52	-	-	-	20.5	20.8	10.5	-	-	-	-	-	-
2 01 05	Alfalfa	7	-	-	-	-	-	-	-	-	-	-	-	7.0
	Bermuda	253	38.3	43.6	44.9	31.2	-	-	-	-	24.6	10.2	46.2	43.6
	Bermuda-Hop Clover	6	-	-	-	-	-	-	-	6.2	-	-	-	-
	Rye-Vetch	10	4.6	-	-	-	5.3	-	-	-	-	-	-	-
	14% Protein Feed	53	-	-	-	-	21.2	20.8	10.8	-	-	-	-	-
2 01 06	Alfalfa	30	-	-	-	-	-	-	-	-	-	7.0	13.7	9.1
	Bermuda	362	40.0	43.1	42.7	53.7	68.2	-	-	-	-	21.1	46.2	47.1
	Bermuda-Hop Clover	13	-	-	-	-	-	-	-	-	13.0	-	-	-
	Rye-Vetch	75	9.2	2.3	-	-	-	12.0	-	29.9	21.2	-	-	-
	14% Protein Feed	42	-	-	-	-	-	18.0	15.9	8.2	-	-	-	-

(Continued)

APPENDIX TABLE A-XVIII (CONTINUED)

Case Number	Hay or Grain Activity	Total Tons	Month Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2 01 07	Alfalfa	30	-	-	-	-	-	-	-	-	-	-	15.1	14.7
	Bermuda	375	52.4	46.6	40.5	40.0	53.2	43.1	-	-	-	-	51.5	47.5
	Bermuda-Hop Clover	15	-	-	-	-	-	-	-	-	-	14.6	-	-
	Rye-Vetch	78	4.8	3.2	2.3	.7	-	-	-	22.3	27.4	17.0	-	-
	14% Protein Feed	41	-	-	-	-	-	-	15.9	17.6	8.0	-	-	-
2 01 08	Alfalfa	16	-	-	-	-	-	-	-	-	-	-	-	16.1
	Bermuda	209	51.0	52.4	40.5	8.8	1.3	2.2	-	-	-	-	-	53.2
	Rye-Vetch	91	11.5	4.8	-	-	-	-	-	-	8.7	10.4	55.9	-
	14% Protein Feed	51	-	-	-	-	-	-	-	20.0	19.5	10.3	1.0	-
2 01 09	Bermuda	179	49.7	46.2	36.5	21.1	-	-	-	25.5	-	-	-	-
	Bermuda-Hop Clover	25	15.5	9.3	-	-	-	-	-	-	-	-	-	-
	Rye-Vetch	118	11.5	6.9	-	-	-	-	-	-	17.0	12.2	49.9	20.2
	14% Protein Feed	50	-	-	-	-	-	-	-	-	19.6	19.6	10.3	-
2 01 10	Bermuda	170	-	46.2	33.4	26.8	-	5.3	-	17.2	40.9	-	-	-
	Rye-Vetch	189	52.7	9.2	-	-	-	-	-	-	-	18.4	42.6	65.6
	14% Protein Feed	46	6.2	-	-	-	-	-	-	-	-	20.2	19.7	-
2 01 11	Bermuda	149	-	-	20.7	37.8	-	17.2	-	7.9	27.3	37.8	-	-
	Rye-Vetch	179	33.6	35.4	-	-	-	-	-	-	-	-	43.9	65.6
	14% Protein Feed	30	9.9	.8	-	-	-	-	-	-	-	-	19.6	-
2 01 12	Bermuda	173	-	26.0	-	39.2	-	17.2	-	.9	8.8	16.7	63.8	-
	Rye-Vetch	119	26.0	27.8	-	-	-	-	-	-	-	-	-	65.6
	14% Protein Feed	29	19.3	9.9	-	-	-	-	-	-	-	-	-	-
2 09 03	Bermuda	220	50.6	71.7	-	-	-	-	7.5	.4	15.0	-	30.8	43.6
	Bermuda-Hop Clover	53	7.8	-	32.9	2.5	-	9.3	-	-	-	-	-	-
	14% Protein Feed	61	-	-	23.6	21.2	12.5	3.9	-	-	-	-	-	-
2 10 03	Bermuda	232	50.6	71.7	-	-	-	-	14.1	6.2	15.0	-	30.8	44
	Bermuda-Hop Clover	70	7.8	-	35.7	8.1	5.6	13.0	-	-	-	-	-	-
	14% Protein Feed	62	-	-	23.7	21.5	12.7	4.0	-	-	-	-	-	-

(Continued)

APPENDIX TABLE A-XVIII (Continued)

Case Number	Hay or Grain Activity	Total Tons	Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2 11 09	Bermuda	307	55.4	55.0	49.3	43.6	40.9	20.7	-	42.4	-	-	-	-
	Rye-Vetch	205	13.8	8.1	6.9	6.0	2.3	-	-	-	24.4	22.5	55.9	64.9
	14% Protein Feed	36	-	-	-	-	-	-	-	-	17.4	17.2	1.0	.7
2 12 03	Bermuda	121	15.8	20.7	-	-	-	-	-	15.8	4.4	-	37.4	26.8
	Rye-Vetch	35	-	-	-	-	-	25.8	3.5	4.8	1.2	-	-	-
	14% Protein Feed	43	-	-	16.3	16.0	9.2	1.0	-	-	-	-	-	-
2 13 03	Bermuda	254	54.6	71.7	-	-	-	-	-	22.9	15.0	6.6	39.2	43.6
	Rye-Vetch	187	2.3	-	49.5	46.0	50.0	35.9	.5	3.2	-	-	1.2	-
	14% Protein Feed	50	-	-	19.4	19.7	10.7	-	-	-	-	-	-	-
2 14 03	Bermuda	258	54.6	71.7	-	-	-	-	-	27.3	15.0	4.8	40.5	43.6
	Bermuda-Hop Clover	11	3.1	-	-	-	-	8.3	-	-	-	-	-	-
	Rye-Vetch	189	-	-	49.5	49.5	57.3	31.5	-	-	-	-	.9	-
	14% Protein Feed	49	-	-	19.4	19.4	10.1	-	-	-	-	-	-	-

APPENDIX TABLE A-XIX

DISTRIBUTION OF HAY FEEDING FOR REPLACEMENT HEIFER SOLUTIONS, TONS PER ACTIVITY PER MONTH

Case Number	Hay Activity	Total Tons	Month Jan - Feb	Mar - Apr	May - Jun	Jul - Aug	Sep - Oct	Nov - Dec
3 15 01	Alfalfa	36	6.7	3.9	5.6	6.3	3.2	9.8
	Bermuda	334	64.2	60.7	-	32.1	36.1	140.4
3 15 02	Alfalfa	42	8.1	4.9	.7	9.1	6.7	12.3
	Bermuda	378	103.4	59.8	-	37.4	44.0	133.8
3 15 03	Alfalfa	53	9.8	6.0	-	13.0	9.1	15.1
	Bermuda	426	140.4	58.5	-	46.6	55.0	125.8
3 15 04	Alfalfa	53	12.3	7.4	-	5.6	10.9	16.5
	Bermuda	431	133.8	97.7	-	31.2	49.3	119.2
3 15 05	Alfalfa	57	14.4	9.5	-	-	15.8	16.8
	Bermuda	431	125.8	135.1	-	17.2	39.6	113.5
3 15 06	Alfalfa	50	16.5	11.9	-	-	3.5	18.2
	Bermuda	386	118.8	126.7	21.6	-	12.3	106.5
3 15 07	Alfalfa	51	16.8	14.4	-	-	-	20.0
	Bermuda	404	113.5	119.2	68.2	4.0	-	99.0
3 15 08	Alfalfa	49	18.2	15.8	2.1	.1	-	12.6
	Bermuda	411	106.5	112.6	63.4	45.8	-	82.7
3 15 09	Alfalfa	49	20.0	16.5	4.9	2.5	-	4.9
	Bermuda	328	99.0	106.9	57.2	84.5	-	69.5
3 15 10	Alfalfa	37	12.6	17.5	.7	.4	-	5.6
	Bermuda	305	82.7	96.8	11.9	46.2	-	67.3
3 15 11	Alfalfa	32	4.9	19.3	.4	.4	-	6.7
	Bermuda	289	69.5	88.4	-	33.4	33.4	64.2
3 15 12	Alfalfa	21	5.6	-	2.8	4.6	-	8.1
	Bermuda	326	67.3	86.7	-	32.1	36.5	103.4

APPENDIX TABLE A-XX

SELECTED ZJ - CJ VALUES FOR INEFFICIENT SOURCES OF ROUGHAGES FROM PROGRAMED RESULTS

Case Number	Activity	ZJ - CJ Value[a]	Upper Limit
1 01 03	Cowpea Pasture	$13.40	4
	Native Hay - Nov.	8.68	12
	Vetch-Oats-Wheat Pasture	12.09	65
	Wheat Pasture	9.78	6
1 01 09	Cowpea Pasture	13.16	70
	Native Hay - Nov.	24.97	5
	Vetch-Oats-Wheat Pasture	12.86	17
	Wheat Pasture	11.50	68
2 01 03	Cowpea Pasture	13.36	145
	Vetch-Oats-Wheat Pasture	12.36	98
2 01 09	Cowpea Pasture	13.13	70
	Wheat Pasture	12.84	173
3 15 03	Cowpea Hay - Nov. - Dec.	11.50	10
	Rye Grass Hay - Nov. - Dec.	7.59	100
	Grain Sorghum Silage - Nov. - Dec.	34.11	24
3 15 09	Cowpea Hay - Jan. - Feb.	11.50	13
	Rye Grass Hay - Jan. - Feb.	7.59	79
	Grain Sorghum Silage - Jan. - Feb.	34.11	19

[a]For interpretation of ZJ - CJ values, see page 29. For a discussion of inefficient sources of roughage, see page 84.

APPENDIX B

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AUTHOR'S EVALUATION OF THE STUDY

When linear programing is used, just as with budgeting, the researcher starts with "ways of combining resources". With linear programing, however, alternative budgets are not developed. Instead, a manipulation of the data is conducted until the optimal or best plan possible is determined. Not only is the best possible plan derived each time, but also the burden of the arithmetic is shifted to the IBM computer. There is no doubt in the author's mind that linear programing was the best tool available for use in achieving the objective of the study.

The roughage systems derived by the study are both reasonable and workable. They can be of special value to dairymen when price and yield data changes are adjusted for by partial budgeting to fit individual farm situations.

Problems encountered in the study probably sound familiar to those experienced with research projects at the master's degree level. Time available for the study was limited. Quantity was given preference over quality in some parts of the analysis. Also, more reading of the literature and more planning prior to beginning the actual study would have improved the efficiency with which the study was carried out. The author recommends that similar studies conducted in the future be narrowed in scope and handled in a more precise manner.

The major limitation encountered in the study was the storage capacity of the IBM 650 computer. This limitation at least doubled the amount of model building and IBM card punching necessary for the programing.

Sixty hours of computer time were used for the study. Approximately one-third, or 20 of the 60 hours, were consumed in de-bugging the model used and in running programs that did not contribute to the final analysis. These 20 hours were an inefficient use of computer time, and the majority of them could have been eliminated by more careful planning.

The opportunity to use the results of prior research in continuing the analysis of least cost roughage systems was very advantageous. The cost and yield coefficients developed by F. J. Smith and used by this study proved to be reliable and beneficial.

As mentioned earlier, time available for the study was limited. Several areas of interest were discovered by the study which could bear investigation. These areas are: (1) roughage systems for high producing dairy cows, (2) the profitability of dry lot dairying in Oklahoma, (3) buying roughage activities for dairy cattle roughage systems, (4) an analysis of the profit maximizing level of feed intake for dairy cows, and (5) development of roughage systems for all major classes of livestock from the basic model used in this study. Adequate treatment of any of the above four areas would necessitate the use of a computer with storage capacity much greater than the IBM 650.

The major benefit derived from the study, I believe, was the research experience gained by the author. Not only was experience gained in research methodology and in the mechanics of carrying out a problem centered research project, but also the author gained experience in choosing and molding a mathematical tool to fit the specific problem at hand. Economic theory was used in development of the mathematical model, and facts from the farm gate level concerning costs and yields were analyzed. Results from the research were interpreted, and alternative courses of action were presented the dairymen.

VITA

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