A LINEAR PROGRAM ANALYSIS OF ROUGHAGE SYSTEMS FOR GRADE A DAIRY FARMS IN GRADY AND LINCOLN COUNTIES

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A LINEAR PROGRAM ANALYSIS OF ROUGHAGE SYSTEMS FOR GRADE

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CHAPTER I

INTRODUCTION

Dairy farmers in Oklahoma have witnessed many technological advances in the development and use of forage crops. A broad selection of new high yielding forages are available in many areas. In a study of 190 farms in the Oklahoma City milkshed, 60 kinds of grazing materials and 53 kinds of hand fed materials were reported.[1] The variety of fed roughages included five kinds of silage and 17 kinds of hay. Hand fed roughage comprised 34 per cent of the annual feed costs. It is apparent that the decisions which the dairyman faces concerning the roughage program are vital to the entire dairy enterprise.

Value of the Study

Many grade A milk producers, while expanding their physical plant and herd size to reduce costs and meet the ever-increasing demands for their product, have continued to rely on inadequate methods for obtaining roughage. Many of these methods were adequate for the less intensive type of dairy farming of past years, but often are major factors limiting the output of and returns to, the more recent specialized dairy enterprises. The introduction and distribution of technical data on new forage crops have kept pace with the development of these crops. The essential problem

[1] F. L. Underwood, _Economic Survey of Resources Used by Dairy Farmers in Oklahoma_, Oklahoma Experiment Station Bulletin, B-42, pp. 9-16.

is that farmers have had to rely on these technical data as a basis for many vital decisions in the realm of economics. In evaluating the roughage program, it is necessary to consider the effects on costs as well as on the physical supply of feed. Certain types of cost information therefore, must be available to the dairyman for a complete economic evaluation of his roughage program. This information at the present time is not available to the dairyman.

The objectives of this study are to provide the information and alternatives necessary for the decision maker to determine the least cost roughage program within the dairy enterprise. Technical data and input costs are compiled and linear programming is used to determine least cost combinations of different sources of roughage which can meet the roughage requirements of the dairy herd. These least cost combinations could be used in their entirety, or as supplements to present programs. The application of these alternatives will enable the dairyman to plan his roughage program in order to meet dairy cow requirements for the least cost.

Sources of Data

This study is based on a survey of 23 Lincoln County and 25 Grady County dairy farms. The climatic conditions for these two counties are similar, as shown in Table I. The results of this study are applicable to any area with climatic conditions corresponding to those shown in Table I. A map of Oklahoma indicating the counties within which the survey took place, and appropriate climatic conditions is presented in Figure 1.

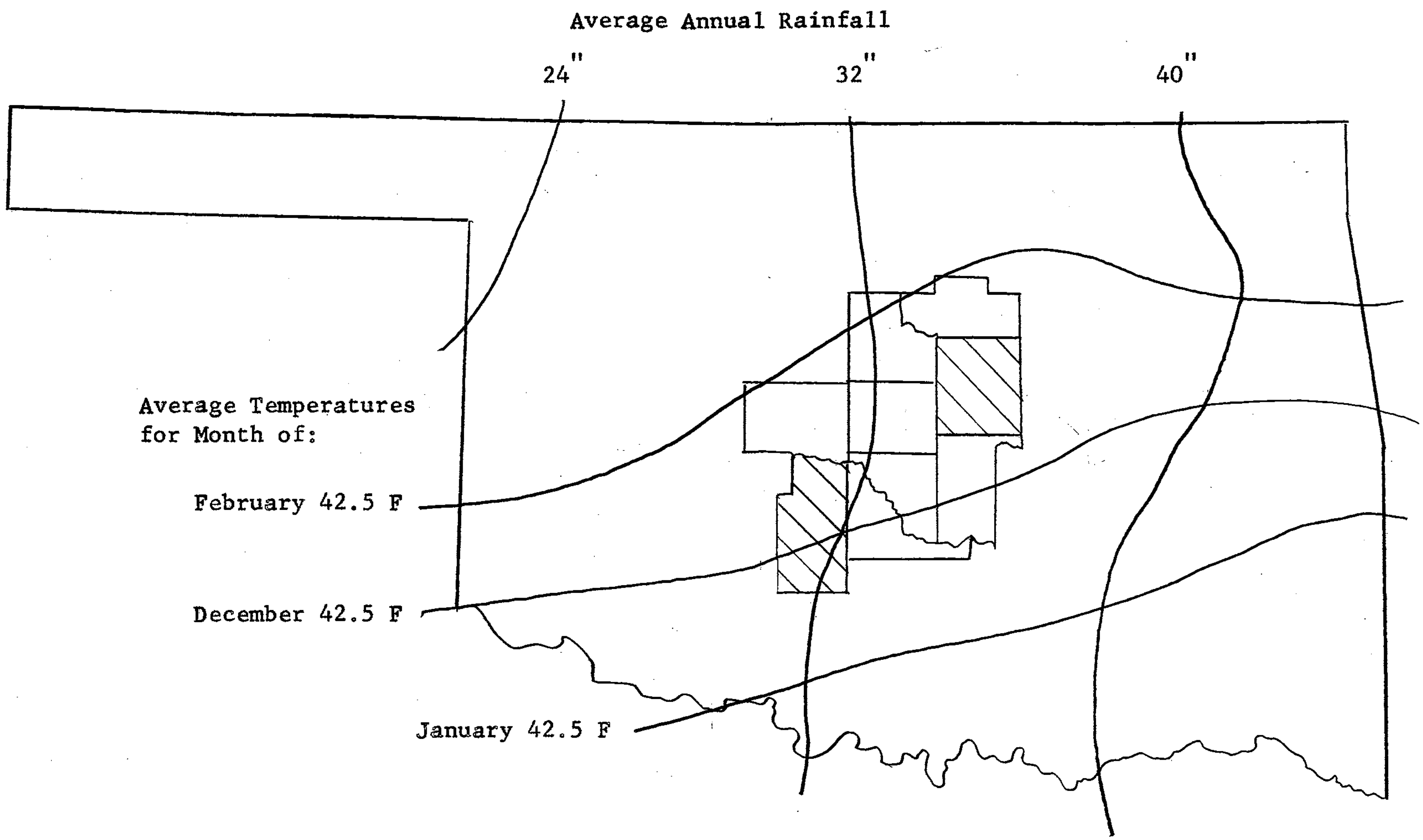

Figure 1. Rainfall and Temperature Areas of Oklahoma

TABLE I

CLIMATIC DATA[a]

	Grady County		Lincoln County	
	1956	1960	1956	1960
Annual Rainfall	24.61	32.37	28.27	34.32
Annual Temperature	63.6	60.4	63.1	60.2
Average Days Grazing		182		174

[a]Climatological Data Oklahoma, United States Department of Commerce.

The 48 farms surveyed were selected on the basis of their milk production capacity and the number of years producing grade A milk. The minimum requirements were at least two years of production of 10,000 pounds of grade A milk per month. This allows greater confidence in the data obtained, as the farms represented were stable, grade A milk producing, dairy farms.

By interviewing each dairyman personally, visual observation and verification of the data was possible. This provided opportunities for obtaining unsolicited information which was quite valuable to the study.

A large amount of secondary information was necessary to establish program coefficients. The primary sources of this data were miscellaneous books, publications and unpublished theses. Valuable information was also obtained from personal interviews with staff members of the Botany, Agronomy, Dairy and Agricultural Economics Departments. The Central Oklahoma Milk Producers Association was especially helpful in providing names and locations of dairymen in its marketing area.

Criteria

This study is concerned with the combinations of roughage producing resources to an individual dairy enterprise. The rational farm manager must allocate his resources by the least cost method. The criterion for determining the least cost method of resource allocation is: if a roughage is used, it is used up to the quantity where the value added is equal to the cost of attaining it. If the cost of roughage used is greater than the value added it will not be used.

In Chapter III a complete model will be presented, showing the tools used in evaluating these costs and returns. The method of linear programming is used in computing least cost combinations of roughage producing resources on dairy farms in central Oklahoma.

CHAPTER II

CHARACTERISTICS OF ROUGHAGE PROGRAMS ON GRADY AND LINCOLN COUNTY DAIRY FARMS

Information used in this study was derived from four sources: (1) previous studies, (2) published experimental results, (3) qualified agricultural scientists, and (4) the farm survey. This chapter describes briefly the characteristics of the dairy farms observed in the survey.

Pasture Acreage

Nineteen hundred and sixty was a good pasture year with rainfall figures slightly above, and temperature slightly below, the long-run average, in both Lincoln and Grady counties. With these climatic conditions prevailing, the acreage distribution of pasture reported in the survey would be close to normal. These conditions may be contrasted to the conditions prevailing in 1956, which was reported as a very poor pasture year.[1]

The pasture systems for Lincoln and Grady County farmers are significantly different. Most pasture in Lincoln County is characterized by native grass and unimproved pastures, while Grady County farmers depend heavily on improved pasture for roughage. An average of 289 acres of native pasture per farm was found on 21 of 23 farms surveyed in Lincoln County. An average of 213 acres per farm on 22 of 25 farms surveyed in

[1] See Table I.

Grady County was in native pasture. An important improved type of pasture in Grady County is Sudan, while in Lincoln County it was somewhat less predominant. Barley pasture was used on two farms in Grady County, averaging 24 acres per farm. Four dairymen were using a native grass, Bermuda grass combination in Lincoln County, with an average of 130 acres per farm.

Lincoln County dairymen depend primarily on native grass pasture, with various types of improved grasses and legumes supplementing the pasture program. In Grady County, improved grass pasture provided an average of 209 acres of grazing. Small grains and legumes are also quite important in Grady County. Although few farmers reported it, it is assumed that Johnson grass is one of the primary sources of roughage on many farms. It is usually unidentified in a mixture of other native grasses by the farmer. Overall, native grass, improved grass, and small grain are the primary components of the pasture programs in this area. Table II provides a summary of acreage and frequency of each type pasture.

TABLE II

PASTURE ACREAGE, GRADY AND LINCOLN COUNTIES (1960)

	25 Grady County Farms		23 Lincoln County Farms	
Type	No. of Farms	Average	No. of Farms	Average
Alfalfa	4	37.75	1	44.00
Barley	2	24.00	0	0
Bermuda	2	18.50	5	66.40
Bermuda-Native	1	80.00	4	130.00
Bermuda-Lespedeza	0	0	3	21.66
Native	22	213.00	21	289.19
Oats	10	43.40	2	22.50
Oats-Vetch	4	76.75	4	83.75
Oats-Wheat	2	31.00	0	0
Rye-Vetch	11	37.64	1	67.00
Sudan	12	30.00	4	33.75
Wheat	13	64.38	3	54.00

Pasture Use

A relatively accurate picture of the number of animal units on each type of pasture, for each month of the year, has been provided by the survey. This measure of pasture utilization as described here does not necessarily correspond to pasture production. In fact, pasture use exceeds pasture production in many instances for the winter months. Livestock are frequently left on pasture during December, January, February and March, but very little feed is actually produced during this time, although some carry-over pasture may be utilized from excess fall pasture. Hand feeding of hay during winter was reported in the majority of cases, and compensated for the limited pasture growth available.

Native pasture is most frequently used for grazing young stock throughout the full grazing season. The milking cows are moved from the native pastures to various other types of pasture as required. A few dairymen prefer to graze one area thoroughly with both young stock and milking cows. The alternative is to graze the improved type of pasture as it becomes available with the milking cows, while holding the native pasture in reserve. Appendix Tables I and II provide more explicit data on the use of the different types of pasture.

Pasture Systems

The pasture systems found on the 48 farms surveyed were grouped into six general categories. Pasture system I is a combination of native pasture, improved grass, small grain and legumes. This pasture system was observed on two Grady County and two Lincoln County farms. Pasture system II, native pasture, improved grass and small grain was observed on five Lincoln County and nine Grady County farms. A combination of native pasture and improved grass composing system III, is represented by three farms in Lincoln County and one farm in Grady County. System IV, improved grass and small grain was observed on seven farms, three in Lincoln and four in Grady County. System V, which is a combination of native pasture and small grain is represented by eight Grady County and three Lincoln County farms, and finally system VI, native pasture, was observed on one Grady County and seven Lincoln County farms.

The relationships between these six pasture systems were analyzed in two ways. An overall ranking of the systems was established, and pasture maps showing yields and variability during the year were estimated.

The ranking of the six pasture systems was accomplished by comparing the average intensity index of all farms in each pasture system. The intensity index is a measure of the days of use for each pasture and is computed by the following:[2]

$$I_i = \frac{1}{AU_i} \sum_{j=1}^{n} \frac{1}{A_{ij}} \sum_{k=1}^{12} AU_{ijk} D_{ijk}$$

where: I_i = Intensity index for the i^{th} farm

AU_i = Total animal units on the i^{th} farm

A_{ij} = Acres of the j^{th} type of pasture on the i^{th} farm

AU_{ijk} = Total animal units on the j^{th} type of pasture on the i^{th} farms in the k^{th} month

D_{ijk} = Days on the j^{th} pasture, i^{th} farm in the k^{th} months.

This index as used in the following analysis indicates the animal unit days per acre weighted by the number of animal units to be pastured.

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[2]See Appendix Tables I and II.

Pasture system IV has the largest intensity index, indicating that its use is greater than that of any other system. Pasture systems II, III, V, and VI were ranked in that order following system IV. The presence of native pasture in the pasture system has a substantial effect on the intensity index. Those pasture systems with large proportions of native pasture have the lower intensity indexes. Pasture system IV, which has the highest index, includes no native pasture. Pasture system VI, with the lowest index, is composed entirely of native pasture. A graphical presentation of the results are shown in Figure 2. Actual computation and numerical procedures are presented in Appendix III.

The establishment of pasture maps for each of the six systems was accomplished by the following procedures. The total number of animal units on the total number of acres for all farms in each pasture system was computed, by months. These figures were converted to TDN consumed per animal unit for each month by estimating the quantity of pasture each cow would consume in one day and applying it to the previous figures. This provided the monthly distributions of pasture use.

Hay and silage feeding was simply taken from the survey data and converted to TDN per animal unit. The average intake of roughage from this data was 4,588 pounds of TDN per head per year.

Costs were estimated for each source of roughage and applied to each of the six pasture systems. These costs are shown on each of the figures 3-8. Appendix Table XV provides the data used in estimating these costs.

Figures 3-8 show the results of the above estimates. Pasture systems II and III provide the most even distribution of TDN over the 12 month

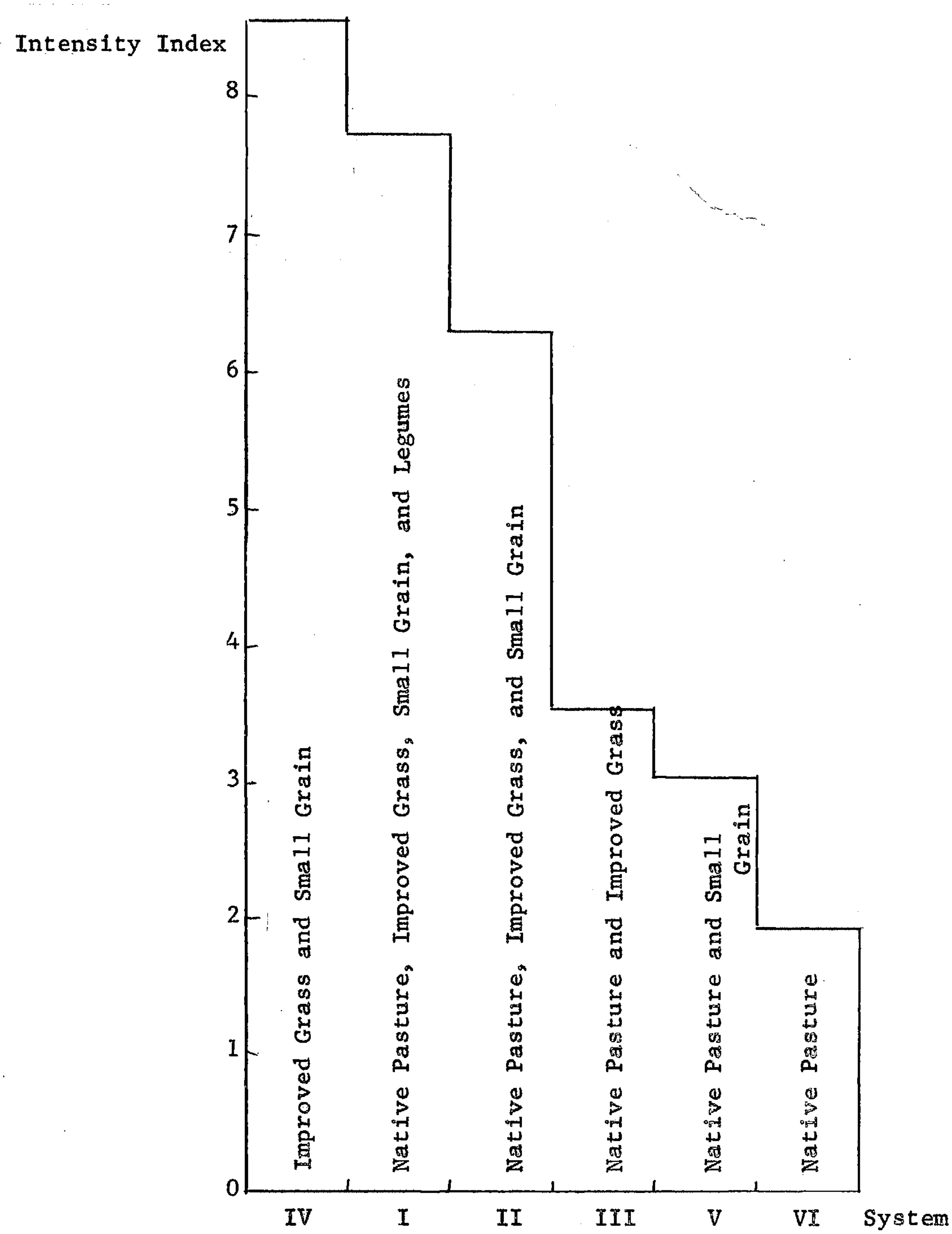

Figure 2. Intensity Index Rank, Six Pasture Systems

period considered. Pasture systems I, IV and VI have less uniform distributive patterns. These pasture use maps reflect consumption of roughage by months. Pasture nutrients were not necessarily consumed in the month they were produced. Pasture production maps would show relatively more pasture in the summer months and less in the winter. Computations corresponding to figures 3-8 are in Appendix Tables IV through IX.

Hay Purchasing

Considerable amounts of hay were purchased by dairy farmers, in both Lincoln and Grady counties. In Lincoln County, 15 farmers purchased an average of 147,200 pounds of hay. The average price paid for all hay was .85 dollars per 100 pounds. In Grady County, 14 dairy farmers purchased an average of 115,315 pounds of hay, which is less than that purchased by Lincoln County farmers, and at a higher average price; 1.13 dollars per 100 pounds. Most Lincoln County dairymen will purchase local native hay rather than pay the transportation costs on alfalfa hay, while Grady County dairymen have adequate quantities of alfalfa hay in their own area.

Hay Harvesting

Over 40 acres of hay were harvested per farm, in Grady County, providing an average of 9,450 pounds for the 22 out of 25 farms that grew it. Alfalfa was the most predominant type of hay grown in both counties, as shown in Table III. Two Lincoln County farms harvested native grass hay, averaging 30 acres per farm. Oats and Sudan were also harvested for hay, but appeared on only four farms, all having small acreages.

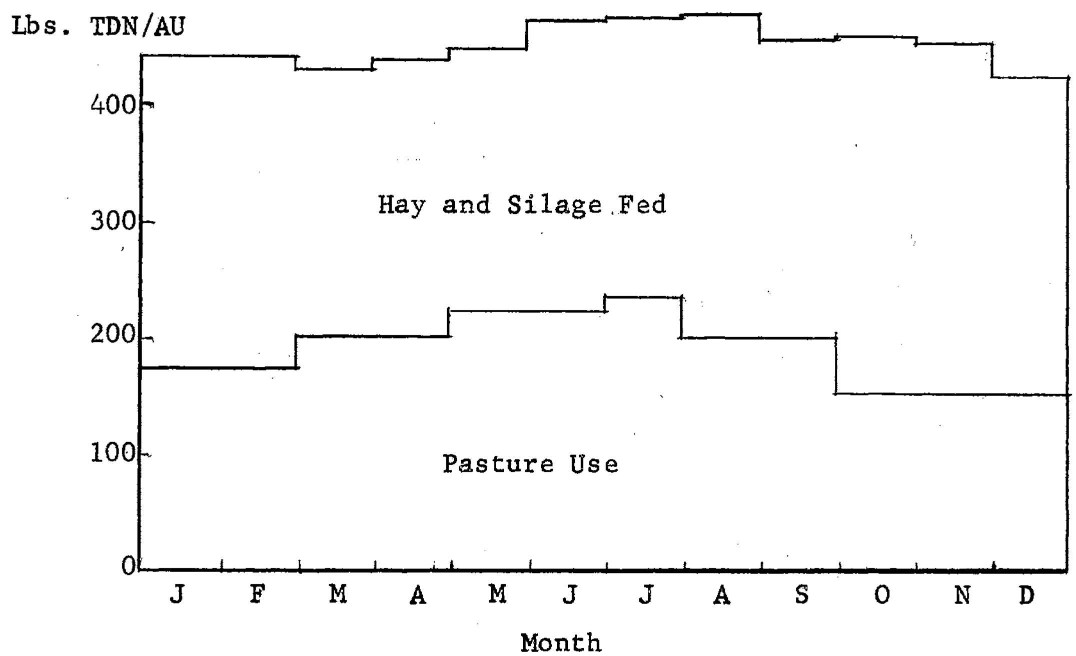

Figure 3. Pasture System I, Total Cost Per Animal Unit = $73.32

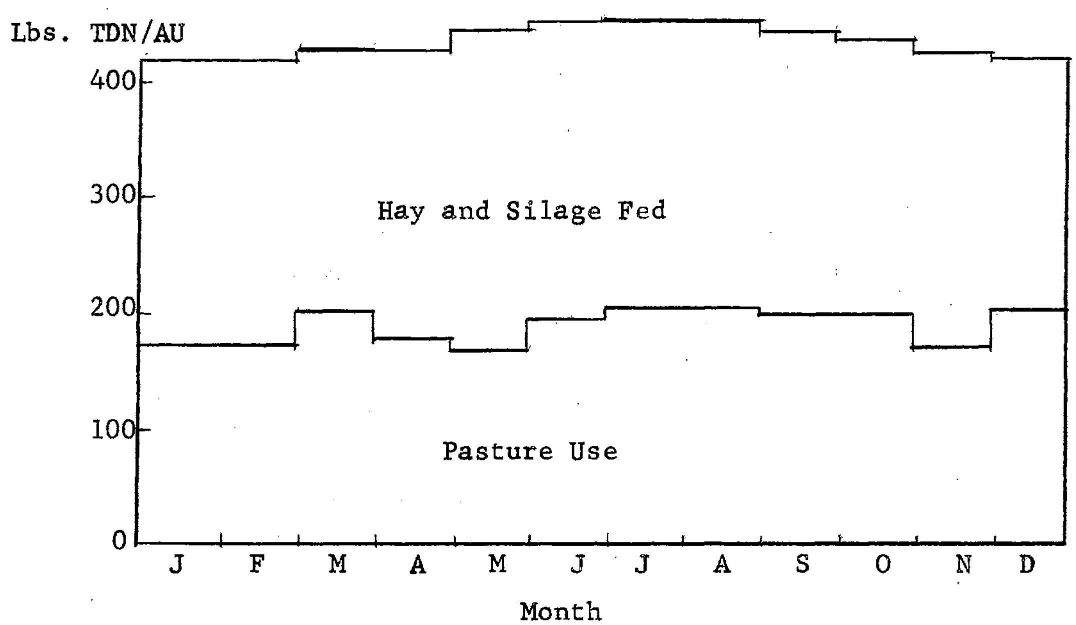

Figure 4. Pasture System II, Total Cost Per Animal Unit = $60.12

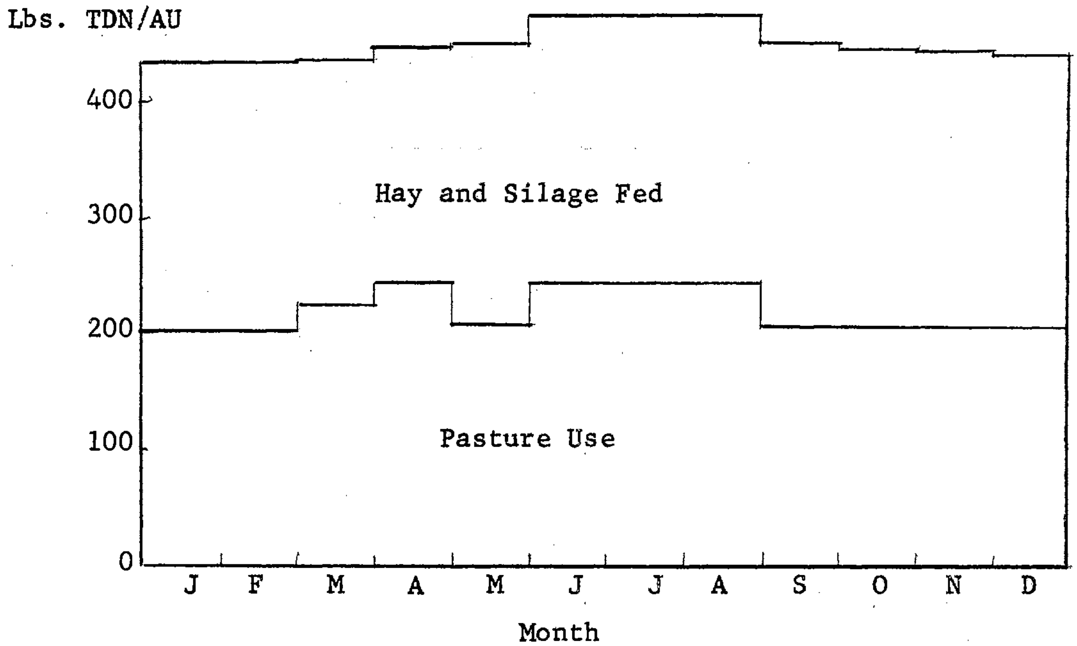

Figure 5. Pasture System III, Total Cost Per Animal Unit = $82.99

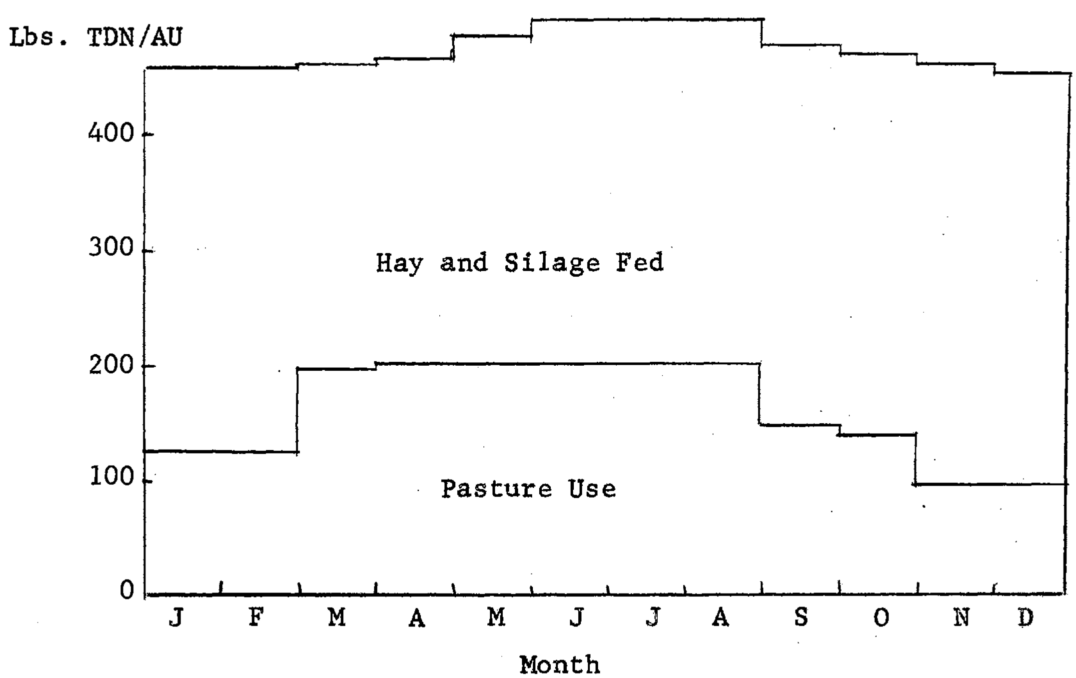

Figure 6. Pasture System IV, Total Cost Per Animal Unit = $73.63

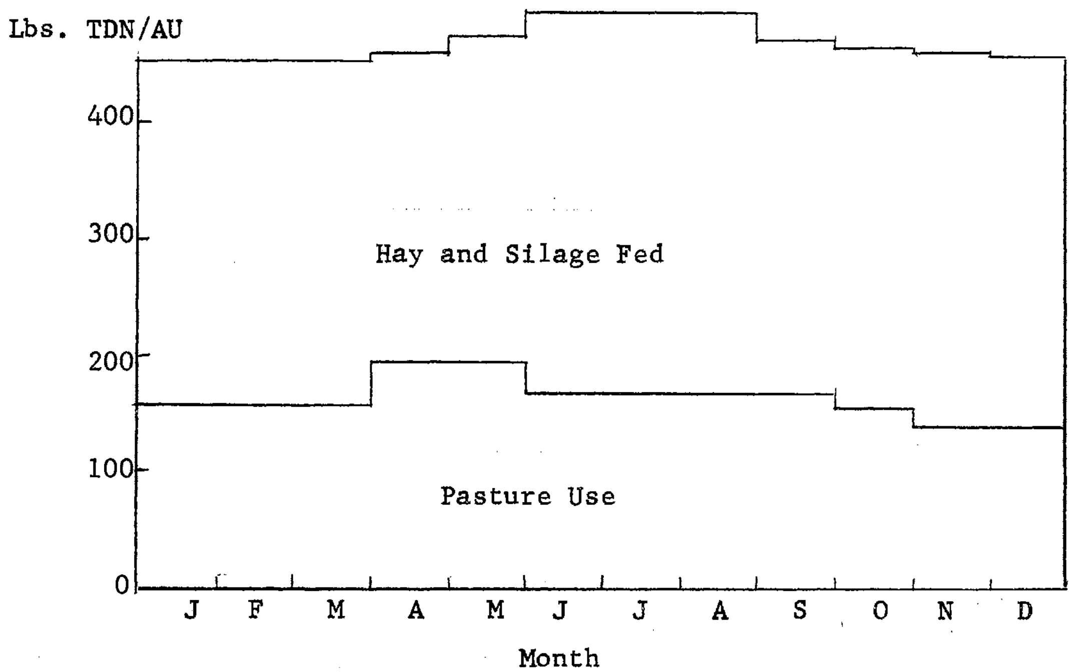

Figure 7. Pasture System V, Total Cost Per Animal Unit = $81.78

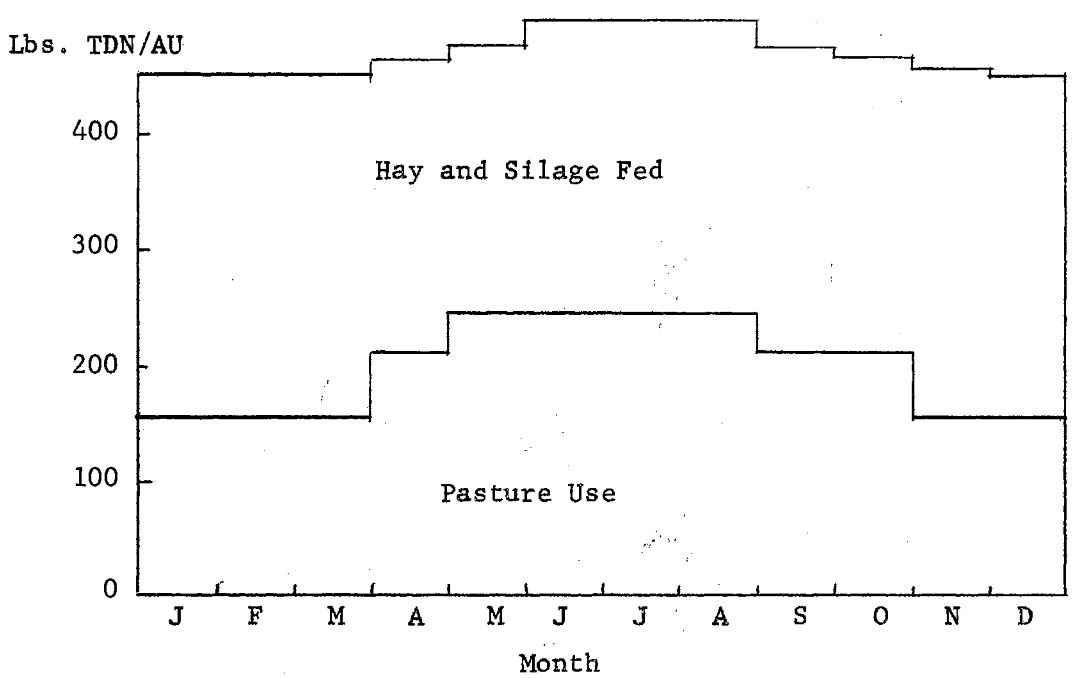

Figure 8. Pasture System VI, Total Cost Per Animal Unit = $58.91

TABLE III

HAY HARVESTED, GRADY AND LINCOLN COUNTIES (1960)

	Grady County Average			Lincoln County Average		
	Acres	Yield (Lbs.)	No. of Farms	Acres	Yield (Lbs.)	No. of Farms
Alfalfa	31.87	9,311	15	34.45	4,658	11
Cowpeas	-	-	-	23.00	2,500	1
Johnson Grass	-	-	-	30.00	2,550	1
Millet	54.33	4,162	3	25.00	4,000	1
Native	-	-	-	30.00	3,330	2
Oats	25.00	3,000	2	39.33	3,667	3
Oats-Vetch	-	-	-	55.66	2,948	3
Sudan	12.50	3,645	2	14.00	6,067	3

Hay Feeding

The total quantity of hay fed to each type of livestock was analyzed for all farms. Total pounds fed in Lincoln County ranged from 1,200 to 7,585 pounds per animal unit, while Grady County farmers reported feeding 517 to 8,806 pounds per animal unit. Most farmers indicated that their heaviest feeding periods were in January and February, although many fed hay all year. The seasonal distribution of hay and silage feeding is shown in figures 3-8.

According to the measures used in this study, there is a tendency for farmers to feed less hay on farms with high pasture use, in both counties, but Lincoln County farmers indicated a relatively greater reduction in hay feeding levels due to greater pasture use.

Silage Harvesting and Feeding

Silage was a minor crop in both counties. An average of 37 acres in Lincoln and 26 acres in Grady County were harvested. Hegari, Sorgo and other types of sorghum were most commonly used for silage. Some Sudan and millet was also cut for silage, but the acreage was minor. Many dairymen in both Lincoln and Grady counties have facilities for handling silage, but have not used these facilities in several years.

A common practice on the observed farms was to feed silage in the fall as the pasture grasses become unavailable. There were ten farms in both Lincoln and Grady counties feeding silage. The minimum amount fed on any one farm was 717 pounds per cow for the season, while the maximum amount fed was 9,200 pounds. Green chopping and feeding was practiced on several farms, primarily as a method of using excess pasture which could not be grazed.

Those dairymen who were actually using silage, apparently were not satisfied with it. Overall, silage and green chop were minor sources of roughage.

CHAPTER III

ANALYTIC PROCEDURES

In this chapter the procedures involved in analyzing production and price information are discussed. The analytical tools are explained and the method of selection of inputs is outlined.

Linear Programming Models[1]

Linear programming is the analytical tool used in this study, for determining the organization of resources to meet the specified criteria. The problem is to minimize the total cost of providing roughage to the dairy animals,

$$(1) \quad TC = \sum_{i=1}^{n} C_i X_i$$

where C_i is the cost of the i^{th} kind of roughage and X_i is the acres of the i^{th} kind of roughage. This equation is subject to restrictions which insure that the amount of roughage required in each month is made available,

$$(2) \quad R_j = \sum_{i=1}^{n} A_{ij} X_i \qquad j = 1, 2, \ldots, 12$$

where R_j is the roughage required in the j^{th} month and A_{ij} is the roughage provided per acre from the i^{th} roughage in j^{th} month.

Additional restrictions insure that the type of land required by the particular roughage is the same as the type of land available,

$$(3) \quad \sum_{j=1}^{n} X_j = A \sum_{k=1}^{n} X_k$$

[1]For a more complete general discussion of Linear Programming see E. O. Heady, Wilfred Candler, Linear Programming Methods (Iowa, 1958).

where the j's are taken over one quality of land, the k's over another, and A is a constant of proportionality reflecting the number of acres of one quality of land available per acre of another quality. If there are three types of land, there would be two equations of type (3), one equation for each proportion or ratio.

An illustration of the model for two months is provided in Figure 9. The conditions for least cost are met at point A, where all sources of roughages are combined in such a manner that the total cost line intersects with both iso-TDN lines and the land proportionality line. The linear program shifts these lines over all dimensions for 12 months and three land qualities until they intersect at a common point. The "Roughage in January" intercept of the land proportionality line is due to land use in other sources of roughage.

Selection of Activities

The determination of activities to be used in equation (1) proceeded as follows. Initially, any method by which the dairyman can obtain roughage for his dairy animals was considered an activity. These activities were reviewed on the basis of climatic, soil, and pathological adaptability to the area in the study. As a result of this selection, activities for producing 20 kinds of hay, 22 kinds of pasture, and 19 kinds of silage as well as buying 10 kinds of roughage were considered for further analysis.

The complete list of these activities is presented in Table VII at the end of this chapter.

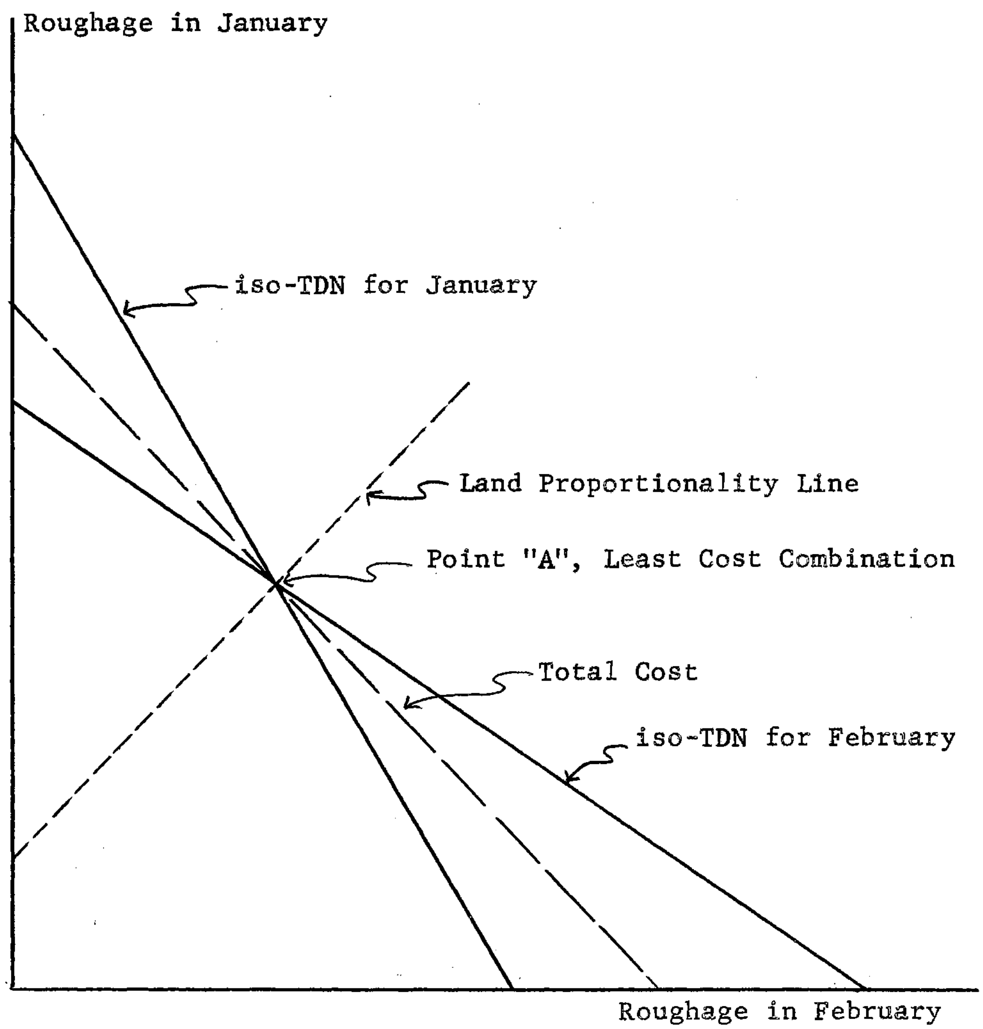

Figure 9. Linear Programming Model

Unit Costs

The costs involved in obtaining each type of roughage were broken down into four general categories: capital charges, establishment costs, harvesting costs, and maintenance costs.

Capital costs include the charge for using land, charge for storage facilities, and charge for depreciation of the roughage during storage. The charge assigned to alfalfa land was $7.00 per acre, based on rental values and interest on capital values.[2] The charge assigned to cropland and native pasture land was $5.00 and $3.00, respectively.

Typical storage facilities included trench silos with 100 ton capacity, pole barns with 100 ton capacity in Grady County and 200 ton capacity in Lincoln County, and frame barns providing up to 30 tons of additional hay storage. The actual cost of depreciation on each of these storage facilities was charged against the type of roughage to be stored in them.[3]

The charge for spoilage and loss was estimated on a per ton basis over the average length of time stored. Since most dairymen feed all their silage in the fall, the opportunity for spoilage is lessened, but is still greater than that for hay. The charge for hay loss and spoilage is prorated over the 12 month period since it is fed throughout this period.

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[2] H. W. Grubb, "A Linear Program Analysis of Grade A Dairy Farm Organizations in the Oklahoma Metropolitan Milk Marketing Area," (Unpublished Master's thesis, Oklahoma State University, 1960), p. 34.

[3] L. J. Connor, W. F. Lagrone and J. S. Plaxico, Resource Requirements, Costs, and Expected Returns; Alternative Crop and Livestock Enterprises; Loam Soils of the Rolling Plains of Southwestern Oklahoma, Oklahoma Agricultural Experiment Station Bulletin, P-368, pp. 6-7.

The costs of buying hay was taken from prevailing market prices. These market prices correspond closely with prices farmers reported paying. Storage and loss charges were applied to purchased roughages as well as home grown roughages, since they are both subject to the same storage and feeding conditions.

Costs of establishment for all types of roughage were estimated. These costs included charges for labor, machinery and equipment, and seed and fertilizer. Labor was valued at $1.00 per hour, which was the wage reported most frequently in the survey. Typical sizes for all machinery and equipment involved were found from the survey data, and appropriate costs of operation and depreciation were used for each particular type of roughage.[4] Custom rates for each operation were compared with the cost of owner-operation. If one involved lower costs than the other for a particular operation, it was used on all types of roughage for that operation. This insures internal consistency and better approximates the actual situation.

Seeding rates and costs as well as fertilizer rates and costs were obtained from the survey data, supplemented by data from various publications and judgments of qualified technicians. The costs of all practices involved in establishment were prorated over the normal life expectancy of the established source of roughage. This placed all costs on a per year basis.

In estimating harvesting costs, a comparison of custom rates and the cost of farmer operation in each activity was necessary. It was

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[4] Ibid., p. 48.

found that whenever custom operation or self operation was cheaper for one activity, it usually was cheaper for all other activities. The charges for labor, power, and equipment are the same as those mentioned previously. Operations such as hauling to the barn or silo and storing away, were considered part of the harvesting costs.

Fence cost or depreciation was charged against pasture as a harvesting cost, since it is necessary in the pasturing process. This cost was charged on a per acre basis for normal pasture size and depreciation of the fence most commonly used on the farms surveyed.

Those crops with a life expectancy of more than one year normally require some maintenance. Clipping weeds, applying fertilizer and reseeding were considered normal maintenance operations. The cost of these operations were estimated on the same basis as the establishment and harvesting costs. Custom operations were considered here also and, when cheaper, were used.

It was found that the operations involved in each activity correspond in most cases with those actually observed in the survey. That is, where custom operation was the least cost, most farmers were using this method. When the cost of owner-operation was less, it was usually used.

Each of the costs outlined above were summarized on a per acre basis, per ton basis, and on a per unit of TDN basis for 71 activities. This provided the cost coefficients for the linear programming model. These costs are presented in Table VII and are used as the C_i in equation (1).

Roughage Requirements

In order to determine the monthly roughage requirements to be satisfied by equation (2) a specified dairy system was determined. The dairy cow which is most representative of those observed in the survey was a 1,500 pound Holstein producing 7,000 to 10,000 pounds of 3.5 per cent butterfat milk per year. The maximum monthly intake of roughage TDN was estimated at 486.18 to 521.94 pounds, depending on the time of year.[5] The system is composed of 100 such dairy animals consuming an estimated 6,000 pounds of roughage TDN each for the year.

A total of 600,000 pounds of roughage TDN is provided for the 100 cows. The pounds of TDN required by the dairy herd in each month are shown in Table IV and are used as the R_j in equation (2).

TABLE IV

MONTHLY ROUGHAGE TDN REQUIREMENTS FOR 100 COWS[a]

Month	Lbs. TDN
January	48,618
February	48,618
March	48,618
April	49,158
May	50,406
June	52,194
July	52,194
August	52,194
September	50,406
October	49,782
November	49,158
December	48,618
Total	600,000

[a]E. J. Nesius, Allocation of Farm Resources for Economic Production of Pasture Forage, Kentucky Agricultural Experiment Station Bulletin 568, p. 6.

[5]F. B. Morrison, Feeds and Feeding (Ithaca, New York, 1951), p. 1032.

Yields

The "A_{ij}" coefficients for equation (2) were determined by analyzing the survey data and experimental results in the area under study. The mean low expected and the mean high expected yields were computed for the supplementary figures and were compared with the figures observed in the study. If the observed figures were between the low expected and the high expected mean they were considered valid for the program. If the observed figures were greater than the high expected mean yield or less than the low expected mean yield, the mean yield was considered valid for the program. For example, the low expected yield for oat pasture was 3,607 pounds per acre, the high expected yield was 7,216 pounds per acre. Since the oat pasture yield observed in the survey was 7,105 pounds per acre, it was considered valid for the program. The pounds per acre yield for each type of pasture was finally converted to pounds of TDN per acre yield by the following transformation function. It was estimated that the mature dairy cow would consume approximately eight pounds of TDN per day on pasture. This was converted to pounds of pasture consumed and multiplied by the animal unit days per acre as follows:[6]

$$\frac{\text{8 Pounds TDN}}{\text{Per Cent Pasture TDN}} = \text{Pounds Pasture/Day}$$

Pounds pasture/day X animal unit days/acre = pounds pasture per acre

Pounds pasture per acre X per cent pasture TDN = pounds TDN per acre.

Table VII lists estimated yields in terms of roughage and TDN for all activities considered in the survey.

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[6]Elmer C. Hunter, Economics of Forage Production, Colorado Agricultural Experiment Station Bulletin, ARS 43-99, p. 52.

To satisfy equation (2) it was necessary to estimate the distributive pattern of the yields for each type of pasture in the program. By again using the survey data (Figures 3-8) and data from various publications it was possible to compute the percentage of the total yield which would be produced in any one month.[7] These figures are presented in Appendix Table XVI.

Yield figures for hay and silage were derived in the same manner as for pasture. No transformation function was necessary for hay and silage as most yields are given in pounds per acre. It was necessary only to convert this to pounds of TDN per acre. Since hay and silage harvested at any time is available for feeding during any month of the year, it was not necessary to estimate distributive patterns.

Land Requirements

All land was classified into three general categories based on the survey data. Land class A_1 was that considered suitable for alfalfa, class A_2 was considered suitable for all other crops except native and unimproved pasture which is classified as land A_3. These three land classes occur in essentially four ratios as derived from the survey data. All farms surveyed were grouped according to the acreage of land suitable to alfalfa. The acreage of the other two classes of land are shown in Table V where each situation represents the different levels of class A_1 land.

[7]H. W. Staten, Grasses and Grassland Farming (New York, 1950), pp. 73-79.

TABLE V

LAND CAPABILITY[a]

Capability (Acres)	Situation 1	2	3	4
A_1 Suitable for Alfalfa	96	48	100	0
A_2 Suitable for Cash Crops	86	115	100	100
A_3 Suitable for Native Pasture	182	344	100	298
Total Acres	364	507	300	398
Per Cent of Farms	30.7	23.1	15.4	30.7

[a]Figures are average for all farms in each group.

The ratios between each class of land were computed from Table V and are shown in Table VI. These ratios are used as the A_j's in equation (3), and insure constant land proportionality while allowing the total land requirement to vary.

TABLE VI

LAND RATIOS AND COEFFICIENTS REPRESENTING TYPICAL FARM SITUATIONS

Situation	A_2/A_1	A_3/A_1	A_2/A_3
1	.897	1.98	.473
2	2.37	7.20	.334
3	1.00	1.00	1.00
4	-	-	.334

TABLE VII

ESTIMATED YIELDS AND COSTS FOR 60 SOURCES OF ROUGHAGE, GRADY AND LINCOLN COUNTIES (1960)

Type of Roughage	Yield: Pounds Roughage Per Acre	Yield: Pounds TDN Per Acre	Cost Per 1,000 Units TDN: Capital	Cost Per 1,000 Units TDN: Establishment	Cost Per 1,000 Units TDN: Harvesting	Cost Per 1,000 Units TDN: Maintenance	Total Cost Per Year: Per 1,000 TDN	Total Cost Per Year: Per Acre	Total Cost Per Year: Per Ton
Alfalfa Pasture	12,451	1,830	$3.95	$1.95	$ .22	$1.89	$8.01	$14.66	
Alfalfa Hay	6,985	3,513	4.30	1.02	8.23	.99	14.53	51.03	14.61
Alfalfa Silage	10,570	1,553	9.21	2.30	17.70	2.23	31.44	48.82	9.24
Bermuda Pasture	5,695	1,424	3.52	.81	.28	1.75	6.35	9.04	
Bermuda Hay	8,810	3,788	2.67	.30	10.10	.33	13.41	50.79	11.53
Bermuda Silage	6,751	1,688	4.48	.68	10.40	.74	16.30	27.51	11.58
Barley Pasture	12,176	1,754	4.00	7.33	.23	0	11.56	20.27	
Barley Hay	2,600	1,406	8.95	7.15	8.16	0	24.26	34.11	26.24
Barley Silage	11,740	1,691	9.75	7.61	13.78	0	31.14	52.66	8.97
Cowpea Pasture	8,000	872	9.07	9.90	.46	.89	20.32	17.72	
Cowpea Hay	2,500	1,235	6.04	6.99	9.53	1.20	23.76	29.34	23.47
Johnson Grass Pasture	9,045	1,492	2.78	1.33	.27	0	4.37	6.53	
Johnson Grass Hay	2,550	1,283	5.14	.96	13.24	.76	20.10	25.79	20.23
Johnson Grass Silage	2,125	702	12.05	1.76	12.03	.88	26.71	18.75	17.65
Hegari Silage	17,747	3,070	6.28	6.21	11.47	0	23.96	73.56	8.29
Lespedeza Pasture	4,841	1,012	6.92	10.00	3.95	0	17.31	17.52	
Lespedeza Hay	4,000	2,088	4.48	4.84	7.90	0	17.22	35.95	17.98
Millet Pasture	4,250	812	6.17	6.43	.49	0	13.09	10.62	
Millet Hay	4,081	2,101	5.15	2.48	7.98	0	15.61	32.80	16.08
Native Pasture	3,490	684	4.37	0	.58	3.63	8.58	5.88	
Native Hay	3,330	1,732	1.76	0	11.95	1.43	15.13	26.20	15.74
Oat Pasture	7,105	1,094	4.66	11.08	.37	0	16.11	17.62	
Oat Hay	3,334	1,544	5.14	7.85	9.36	0	22.35	34.51	20.70
Oat Silage	13,200	2,033	7.43	5.96	12.89	0	26.28	53.43	8.10

(Continued)

TABLE VII (Continued)

Type of Roughage	Yield: Pounds Roughage Per Acre	Yield: Pounds TDN Per Acre	Cost Per 1,000 Units TDN: Capital	Cost Per 1,000 Units TDN: Establish-ment	Cost Per 1,000 Units TDN: Harvest-ing	Cost Per 1,000 Units TDN: Mainte-nance	Total Cost Per Year: Per 1,000 TDN	Total Cost Per Year: Per Acre	Total Cost Per Year: Per Ton
Rye Grass Pasture	12,075	1,830	2.74	.53	.22	1.44	4.92	9.00	
Rye Grass Hay	2,500	1,128	6.60	.86	10.37	2.34	20.17	22.75	18.20
Rye Pasture	4,966	804	6.34	14.50	.50	0	21.34	17.16	
Rye Silage	14,125	2,288	6.89	5.09	12.25	0	24.23	55.44	7.85
Sudan Pasture	6,753	1,181	4.24	4.88	.34	0	9.46	11.17	
Sudan Hay	4,856	2,355	4.87	2.45	8.17	0	15.49	36.47	15.07
Sudan Silage	39,727	7,032	4.90	.82	11.21	0	16.93	119.04	5.99
Sorghum (Sweet) Pasture	5,233	905	7.73	21.09	.44	0	29.26	26.48	
Sorghum (Sweet) Silage	25,397	4,394	5.58	4.34	15.03	0	24.95	109.63	8.63
Sorghum (Grain) Silage	18,500	3,200	6.19	6.06	11.47	0	23.72	75.90	8.21
Vetch Pasture	3,249	396	17.69	3.37	1.01	2.40	24.47	9.69	
Wheat Pasture	8,375	766	9.14	16.99	.52	0	26.65	20.42	
Bermuda-Lespedeza Pasture	5,254	1,203	4.16	3.11	.33	2.39	9.99	12.02	
Bermuda-Lespedeza Hay	6,000	2,856	2.97	1.31	10.24	.57	15.09	43.11	14.37
Bermuda-Hop Clover Hay	6,170	2,869	2.99	1.31	10.39	.40	15.09	43.28	14.03
Oats-Rye Pasture	5,184	819	6.35	13.90	.49	0	20.74	16.99	
Oats-Rye Hay	3,000	1,365	4.79	8.34	9.79	0	22.92	31.48	20.99
Oats-Rye Silage	9,500	1,501	7.69	7.59	16.46	0	31.74	47.64	10.03
Oats-Vetch Pasture	5,087	870	5.98	15.56	.46	0	22.00	19.14	
Oats-Vetch Hay	2,948	1,548	4.34	8.64	8.53	0	21.51	33.30	22.59
Oats-Vetch Silage	19,525	3,339	5.08	4.51	15.20	0	24.79	82.76	8.48
Rye-Barley Pasture	5,812	889	5.85	13.24	.45	0	19.54	17.37	
Rye-Barley Hay	3,000	1,482	4.54	7.94	9.03	0	21.51	31.88	21.25
Rye-Barley Silage	10,500	1,607	7.32	7.32	16.99	0	31.93	51.31	9.77
Rye-Vetch Pasture	9,914	1,408	3.69	9.72	.28	0	13.70	19.29	
Rye-Vetch Hay	4,500	2,372	3.21	5.77	7.67	0	16.65	39.49	17.55
Rye-Vetch Silage	19,500	2,059	7.28	6.65	18.31	0	32.24	66.39	6.81

(Continued)

TABLE VII (Continued)

Type of Roughage	Yield: Pounds Roughage Per Acre	Yield: Pounds TDN Per Acre	Cost Per 1,000 Units TDN: Capital	Cost Per 1,000 Units TDN: Establishment	Cost Per 1,000 Units TDN: Harvesting	Cost Per 1,000 Units TDN: Maintenance	Total Cost Per Year: Per 1,000 TDN	Total Cost Per Year: Per Acre	Total Cost Per Year: Per Ton
Oats-Barley-Rye Pasture	5,927	871	5.97	13.43	.46	0	19.86	17.30	
Oats-Barley-Rye Hay	3,000	1,452	4.64	8.06	9.21	0	21.91	31.81	21.21
Oats-Barley-Rye Silage	11,000	1,617	7.78	7.19	17.69	0	32.66	52.81	9.60
Vetch-Oats-Barley Pasture	5,889	954	5.45	14.62	.42	0	20.49	19.55	
Vetch-Oats-Barley Hay	3,500	1,855	3.78	7.52	6.89	0	18.19	33.74	19.28
Vetch-Oats-Barley Silage	13,250	2,147	6.59	6.49	16.05	0	29.13	62.54	9.44
Vetch-Oats-Wheat Pasture	4,743	678	7.68	2.22	.59	0	30.49	20.67	
Vetch-Oats-Wheat Hay	3,500	1,757	3.96	8.57	8.53	0	21.06	37.00	21.14
Vetch-Oats-Wheat Silage	13,500	2,133	7.17	7.06	18.18	0	32.41	69.13	10.24

CHAPTER IV

PROGRAMMED RESULTS

In Chapter II the roughage systems used by 48 Grady and Lincoln County dairy farmers in 1960 were discussed. The tools and data required for an analysis of least cost roughage systems were presented in Chapter III. In this chapter, eighteen roughage systems reflecting the least cost combination of activities under specified conditions are presented and discussed. These roughage systems are grouped according to the four land situations observed. Optimal solutions are shown for each land situation, using the costs listed in Table VII. Near optimal solutions are also derived by denying the use of certain unstable activities. An unstable activity is one for which a small change in the cost would induce a new solution. "The implication is that if all other cost coefficients remain fixed, the cost coefficient of the activity in question, may change to any value within the stated range without effecting optimality."[1]

The quantities of land used for each activity and the amounts of roughage provided in each month are reported for each solution. The annual distribution of total pasture yields and the allocation of hay feeding among months is determined by the program in a manner which satisfies the total monthly TDN requirements. Total TDN produced from pasture per year equals total TDN consumed, but pasture consumption may be distributed as

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[1] O. R. Perry and J. S. Bonner, Linear Programming Code for the Augmented 650, File Number 10.1.006.

in the pasture maps of Chapter II, which means that consumption may diverge from pasture production for any given month.

The analysis throughout this chapter considers each case individually in terms of its economic, botonical and nutritional feasibility. A general discussion and comparison of all cases will be presented in Chapter V.

Application of Results

A dairyman may determine which of the four programmed land situations approximates his farm by classifying the farm land available for use in the dairy enterprise into the three categories discussed in Chapter III. The number of acres in the first category, A_1, is divided into the number of acres in the A_2 and A_3 types of land, giving a set of ratios.

The roughage systems presented in this chapter are general in their application because simple modifications in the results adapt them to alternative herd sizes, levels of roughage feeding and acreages.

Each roughage system is based on 100 cows, but the results may be adjusted to any herd size by dividing through by 100 and multiplying by the number in the farm herd. For example, if the optimal roughage system for 100 cows costs \$5,000 per year and uses 200 acres, then roughage for a 45-cow herd (the sample average herd size) would cost,

$$\frac{\$5,000}{100 \text{ cows}} \times 45 \text{ cows} = \$2,250$$

and would use,

$$\frac{200 \text{ acres}}{100 \text{ cows}} \times 45 \text{ cows} = 90 \text{ acres.}$$

The programmed results are based on consumption of 6,000 pounds of TDN from roughage per cow, per year. This is the maximum annual roughage intake for a 1,500 pound cow producing 8,000 to 10,000 pounds of 3.5 per cent milk, and according to F. B. Morrison's feeding standards would require approximately 1,835 pounds of additional TDN per year from concentrates. The dairyman may feed less than 6,000 pounds of TDN from roughage per cow, and the program results are adaptable to any level of roughage and/or concentrate intake. For example, if the decision maker desires to feed 4,588 pounds of TDN in the form of roughage (sample average), the appropriate cost for 100 cows in the above example would be:

$$\frac{4{,}588 \text{ pounds}}{6{,}000 \text{ pounds}} \times \$5{,}000 = \$3{,}823$$

or number of cows that could be handled for $5,000 cost on 200 acres would be:

$$\frac{6{,}000 \text{ pounds}}{4{,}588 \text{ pounds}} \times 100 \text{ cows} = 131 \text{ cows.}$$

To determine the carrying capacity of farms of given size, divide the number of programmed acres by 100 to get acres per cow. The acres required per cow is then divided into the total farm acres to find the possible herd size for this program. For example, if programmed results are as above and the number of acres in the farm is 296 (sample average), the number of cows which could be handled is:

$$\frac{200}{100} = 2 \text{ acres/cow}$$

$$\frac{296}{2} = 148 \text{ cows}$$

and the total cost for these 148 cows is:

$$\frac{\$5{,}000}{100} \times 148 = \$7{,}400.$$

Interpretation of Activities

Pasture producing activities are identified in each of the roughage systems or cases presented by the acres required for 100 cows. Hay producing activities are identified by tons of yield as well as acres used. Hay buying activities are identified by a given cost per 1,000 pounds of TDN and the number of tons of TDN to be purchased. Since different quantities of each type of hay are required to supply any given quantity of TDN, the cost per ton of each type of hay differs for a given cost per 1,000 pounds of TDN. Table VII presents the costs per ton for the more common types of purchased hay, and for six levels of cost per 1,000 pounds of TDN, three of which appear in the programmed solutions. In this table, the decision maker would be indifferent between the price of hay per ton for any given cost per 1,000 pounds of TDN.

In Tables X through XII, purchased roughage is given in tons of TDN. To convert tons of TDN to tons of hay to buy, for each type of hay, the dairyman must refer to Table IX which provides these conversion rates for all levels of TDN appearing in Tables X through XII.

Purchased silage would substitute for purchased hay, but is not shown in the tables because the prices of purchased silage reported by farmers in the survey were high relative to hay prices.

TABLE VIII

PRICES OF PURCHASED HAY CORRESPONDING TO COSTS PER 1,000 POUNDS OF TDN (AT THE FARM GATE)[a]

Cost Per 1,000 Pounds TDN	Price Per Ton Hay For:					
	Alfalfa	Bermuda	Native	Johnson Grass	Millet	Sudan
$11.56	$11.62	$9.94	$12.04	$11.56	$11.91	$11.21
13.28	13.36	11.42	13.81	13.28	13.68	12.88
14.27	14.35	12.27	14.84	14.27	14.70	13.84
18.47	18.58	15.88	19.21	18.47	19.02	17.92
23.59	23.72	20.29	24.53	23.59	24.30	22.88
24.19	24.33	20.80	25.16	24.19	24.91	23.46

[a]Approximately $1.20 per 1,000 pounds of TDN would be added to obtain the cost at the cow's mouth.

TABLE IX

TONS OF PURCHASED HAY CORRESPONDING TO TONS OF TDN

Tons of TDN	Tons of Hay For: Alfalfa	Bermuda	Native	Johnson Grass	Millet	Sudan
167	332	388	321	334	324	344
150	298	349	288	300	291	309
146	290	339	281	292	283	301
100	199	232	192	200	194	206
99	197	230	190	198	192	204
74	147	172	142	148	144	153
49	97	114	94	98	95	101

Results for Land Ratios $1A_1$: $.897A_2$: $1.98A_3$

The proportion of total farm land suitable for alfalfa in Grady County is relatively large. A typical farm situation corresponding to the land ratios $1A_1$: $.897A_2$: $1.98A_3$ would include 96 acres of alfalfa land out of a total of 364 acres. The amount of land type A_2, that is suitable for cropping, would be about 86 acres and A_3 land, native pasture, 182 acres. If the ratios of the three land types as determined by the dairyman are approximately the same as the above ratios, the following analysis is applicable. Seven least cost roughage systems under specified sets of conditions are presented in Table X.

Case 1

This case provides the required annual roughage TDN for \$5,537, which makes it the lowest cost case. The 180 acres of land required is used by 90 acres of Johnson grass pasture on the class A_3 land, 39 acres of rye grass plus four acres of rye-vetch pasture on the class A_2 land and 47 acres of alfalfa on the class A_1 land. This combination of pasture is

TABLE X

PROGRAMMED RESULTS FOR LAND RATIOS $1A_1$: $0.897A_2$: $1.98A_3$, PROVIDING THE LEAST COST ANNUAL ROUGHAGE REQUIREMENT FOR 100 ANIMAL UNITS

	Case 1			Case 2			Case 13			Case 21		
Activity	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons
A_1 Land												
Alfalfa Pasture	No	47		No	47		No	74		No	81[b]	
Grow Alfalfa Hay	No	0	0	No	0	0	No	0	0	No	0	0
A_2 Land												
Rye-Vetch Pasture	No	4		No	0		No	0		No	0	
Rye Grass Pasture	No	39		No	39[bc]		No	0		Yes	0	
Grow Bermuda Hay	No	0	0	No	4[bc]	18	No	66	291	No	73[b]	322
Grow Millet Hay	No	0	0	No	0	0	No	0	0	No	0	0
A_3 Land												
Johnson Grass Pasture	No	90		No	90		No	116		No	85[c]	
Native Pasture	No	0		No	0		No	0		No	69[b]	
Grow Native Hay	No	0	0	No	0	0	No	23	39	Yes	0	0
Buy Hay at:[a]												
\$11.56/1,000 TDN	No		150[b]	Yes		0	Yes		0	Yes		0
\$13.28/1,000 TDN	No		0	No		146[bc]	Yes		0	Yes		0
\$14.27/1,000 TDN	No		0	No		0	No		0	No		0
Total Acres		180			180			279			308	
Total Cost		\$5,537[e]			\$5,709[e]			\$5,804			\$5,852	

(Continued)

TABLE X (Continued)

Activity	Case 31 Activity Denied?	Case 31 Acres	Case 31 Tons	Case 38 Activity Denied?	Case 38 Acres	Case 38 Tons	Case 35 Activity Denied?	Case 35 Acres	Case 35 Tons
A_1 Land									
Alfalfa Pasture	No	49[c]		No	86		No	18	
Grow Alfalfa Hay	No	21[b]	733	No	0	0	No	63	220
A_2 Land									
Rye-Vetch Pasture	No	0		No	8		No	46	
Rye Grass Pasture	Yes	0		Yes	0		Yes	0	
Grow Bermuda Hay	No	63[c]	278	No	68[c]	300	Yes	0	0
Grow Millet Hay	No	0	0	No	0	0	No	26	53
A_3 Land									
Johnson Grass Pasture	No	133[b]	0	No[d]	75[bc]		No	152	
Native Pasture	Yes	0		No	87[bc]		No	0	
Grow Native Hay	Yes	0	0	Yes	0	0	Yes	0	0
Buy Hay at:									
$11.56/1,000 TDN	Yes		0	Yes		0	Yes		0
$13.28/1,000 TDN	Yes		0	Yes		0	Yes		0
$14.27/1,000 TDN	No		0	No		0	No		0
Total Acres		266			324			305	
Total Cost		$5,852			$6,122			$6,197	

(Footnotes continued)

TABLE X (Continued)

[a]See Table VIII and IX for the per ton cost and tons of hay which would be purchased at each of the given costs per 1,000 pounds of TDN.

[b]Indicates that the cost of the activity is within one dollar of the upper bound of the shadow price, implying relative instability in the optimal solution.

[c]Indicates that the cost of the activity is within one dollar of the lower bound of the shadow price, implying relative instability in the optimal solution.

[d]Indicates that input cost was raised, but not by an amount sufficient to deny entry.

[e]Total cost includes storage, spoilage, loss and handling charge on purchased hay, or approximately $1.20 per 1,000 pounds of TDN added to the purchase price at the farm gate to obtain cost at cow's mouth.

supplemented by feeding 150 tons of TDN from purchased hay at $11.56 per 1,000 TDN. This is equivalent to 298 tons of alfalfa hay at $11.62 per ton or 288 tons of native grass hay at $12.04 per ton. The total cost of $5,537 per 100 cows includes a $360 hay handling charge. This amounts to $1.20 per 1,000 TDN in addition to the $11.56 purchase price reported in the table. (See footnote, Table VIII.)

All activities are stable in this case except the hay buying activity. If the price of hay increases more than $.87, less than 150 tons of TDN from purchased hay would be used.

The distribution of the TDN obtained from the combined pasture systems and the feeding of roughage is presented in Figure 10. Most hay is fed between November and February when pasture yields are low.

The class A_1 land is best suited to alfalfa pasture in this case, since there are no alternative uses of this land which will provide equivalent high quality roughage at such low costs. The rye grass pasture provides a source of roughage comparable to cereal grain pasture. It is also the most important source of pasture on the class A_2 land. Johnson grass pasture is indicated as the best source of roughage on the class A_3 land. The fertility requirements of Johnson grass are such that it could be grown only on the best class A_3 land.

The digestible protein provided by pasture in case 1 is in surplus during the summer months when cows are on alfalfa pasture, but would probably be inadequate during the hay feeding season since low protein (4.9% DP) native grass hay is the only type of hay likely to be purchased and fed for $11.56 per 1,000 TDN. The low protein may be compensated for by feeding a 20 to 24 per cent protein concentrate during the hay feeding period and a 16 to 18 per cent concentrate during the pasture months.

Other, possibly cheaper methods, of providing this protein will be shown in the following cases.

This roughage system depends heavily upon a good supply of purchased roughage at a low price. It would be desirable to examine least cost roughage combinations when purchased hay prices are higher than assumed for case 1.

The following cases examine this and other alternatives in finding the least cost roughage system.

Case 2

When purchased hay costs $13.28 per 1,000 TDN, case 2 in Table X provides the least cost roughage combination. Total annual cost is $5,709, representing a $130 increase due to reorganization of activities and a $46 increase due to the higher cost of hay, over case 1, while the land requirement remains the same. Eighteen tons of Bermuda grass hay are produced on four acres of class A_2 land, replacing 4,000 TDN of purchased hay and the rye-vetch pasture. The Bermuda hay allows some variety in hay feeding if the 146 tons of purchased TDN is provided by 281 tons of native hay at $13.81 per ton or by 290 tons of alfalfa hay at $13.36 per ton. Johnson grass, rye grass and alfalfa pasture are all used by the dairyman at the same levels as in case 1.

The annual distribution patterns of pasture yields and hay feeding are shown in Figure 11. The full TDN requirements are obtained from pasture during July and September.

Rye grass pasture, hay buying and growing Bermuda hay are all unstable activities in this case. Relatively small variations in yields and/or costs of these activities could make other combinations of roughage

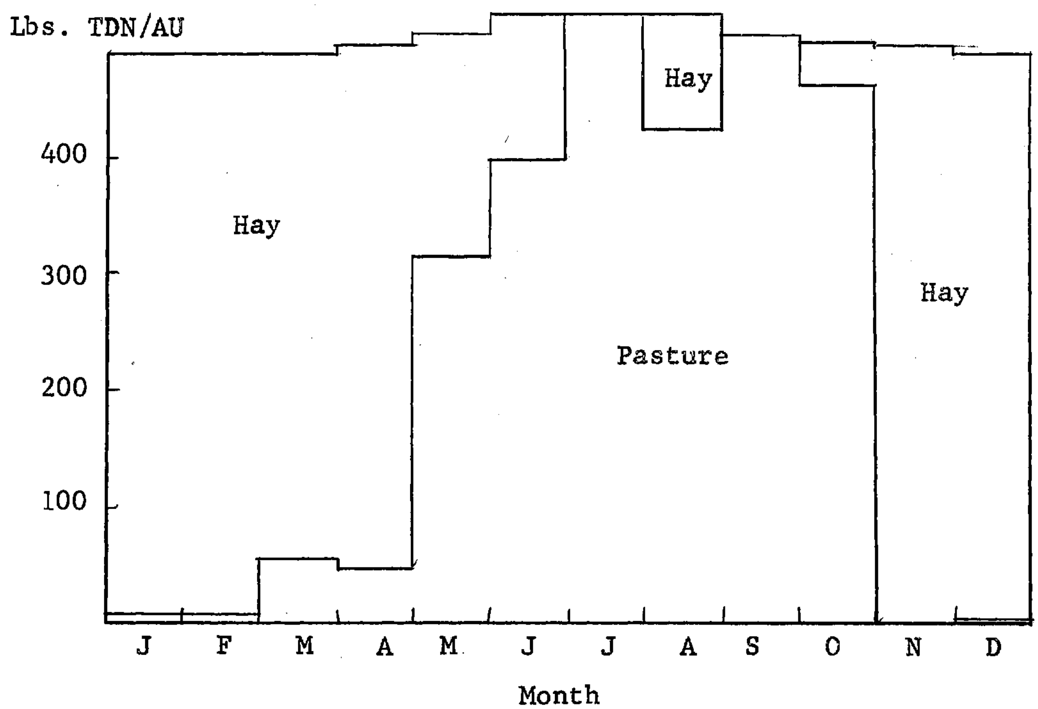

Figure 10. Case 1

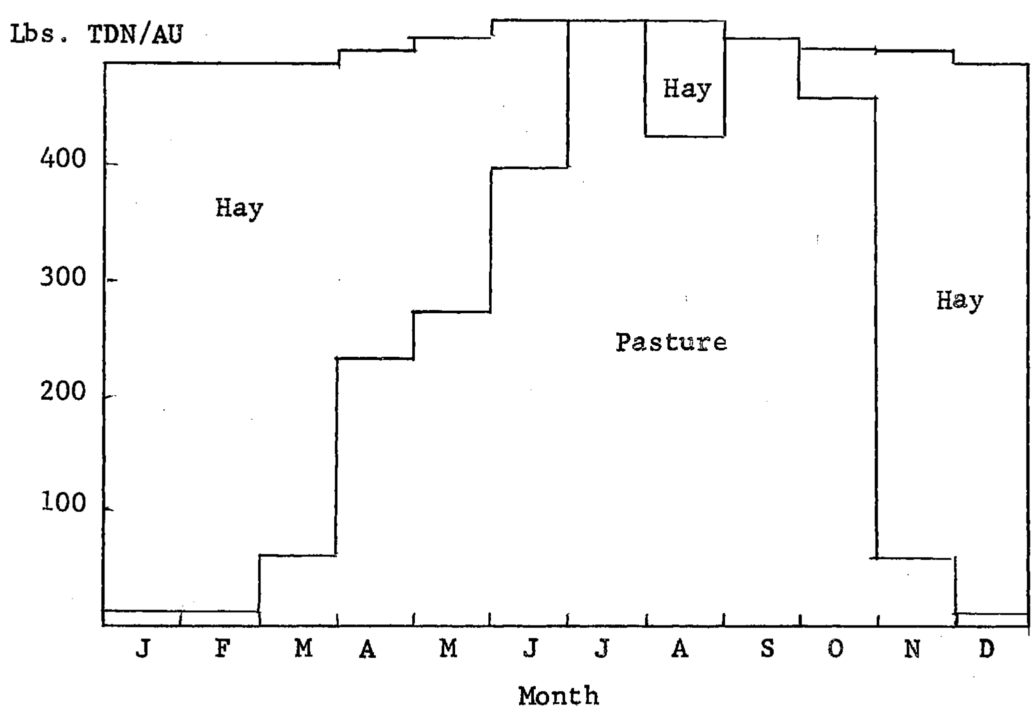

Figure 11. Case 2

producing activities cheaper. The next case examines the least cost combinations when the cost of buying hay is increased.

Case 13

When hay buying is priced at $14.27 per 1,000 TDN, hay is not purchased in the optimal solution. Total annual cost is $5,804 and total land required increases to 279 acres as shown in Table X. The hay buying activity is replaced by Bermuda and native hay growing activities contributing to the increase in total acreage and cost. Sixty-six acres of Bermuda grass, yielding a total of 291 tons of hay, and 23 acres of native grass yielding a total of 39 tons of hay would be harvested by the dairyman. Native grass hay and Johnson grass pasture use all of the class A_3 land available in this program. Bermuda grass hay uses all of the class A_2 land while alfalfa pasture uses all of the class A_1 land.

The distribution of total pasture yields are quite uniform between April and October as shown in Figure 12. Hay would be fed in every month except September, with the majority being fed in the winter months, November through March.

The above combination of activities is stable, since all input costs are well within the shadow prices. The quantities of land for each activity are of sufficient magnitude, to allow the dairyman to establish and maintain the indicated activities at costs close to those shown in Table VII.

Since no additional legume is available in this program, and there are indicated periods of all hay feeding, the dairy animals would have to depend entirely on grass type hay for their roughage during the winter. An even higher protein concentrate ration would be fed in this case than for case 1, during the all hay feeding period because Bermuda hay has less digestible protein per pound of TDN than native grass hay. Some variety is present in this roughage program, which is a considerable improvement, but it does not compensate for the deficiency in certain nutrients.

Harvesting of 23 acres of native grass hay in case 13 may not be possible on many farms due to the nature of the pasture. The presence of gulleys, steep slopes and other obstacles such as woody growth may prevent the use of harvesting equipment in an efficient manner. The remaining cases for the land ratio under discussion do not allow native hay harvesting for this reason.

Case 21

When the input costs of rye grass pasture, harvesting native grass hay and hay buying are raised to a level which eliminate them from the optimal solution, the land requirement and costs of production both increase. The results of these cost changes are shown in case 21 of Table X. The cost increases are attributable to adjustments in activity levels and not to input cost changes since no activities with cost changes are in the solution. Total land requirement is 308 acres, an increase of 29 acres over case 13 and 128 acres over cases 1 and 2.

Johnson grass and native grass pasture appear together in this program and require 154 acres of class A_3 land. Seventy-three acres of Bermuda grass provide 322 tons of hay and use all of the class A_2 land. Alfalfa pasture is again the only activity on the class A_1 land, requiring a total of 81 acres.

This program provides greater quantities of pasture TDN relative to hay than any previous program. The pasture yields are higher and extended over a longer season. Smaller amounts of hay are fed, especially during the summer months. The winter period between November and March is again the heaviest hay feeding period, as indicated in Figure 13. Since Bermuda grass hay is the only type of hay available in this program, there is no opportunity for the dairyman to feed a mix or variety of roughage during the winter months. The 81 acres of alfalfa pasture would provide an excellent source of roughage when combined with the native and Johnson grass pastures in the summer, but milk production is likely to drop as Bermuda grass hay becomes the primary source of roughage.

A higher protein concentrate ration may be fed during the Bermuda hay feeding period to maintain milk production, or, as will be shown in the following case, alfalfa hay may be substituted for any other activity with slight cost changes and provide a higher protein source of hay. Possible adjustments within the program would allow some of the alfalfa pasture land to be transferred into hay production while Bermuda hay land could be used as pasture.

Case 31

When the input cost of native pasture is changed from $5.87 per acre to $5.90 per acre, no change occurs in annual total cost while there is a decrease in total land requirement when compared to case 21.

With this roughage program the dairyman would not grow native pasture but would grow alfalfa hay on 21 acres of class A_1 land producing 733 tons. Forty-nine acres of alfalfa pasture would be grown on the remaining class A_1 land. Sixty-three acres of Bermuda grass are required, producing 278 tons of hay on the class A_2 land. All class A_3 land is used by Johnson grass.

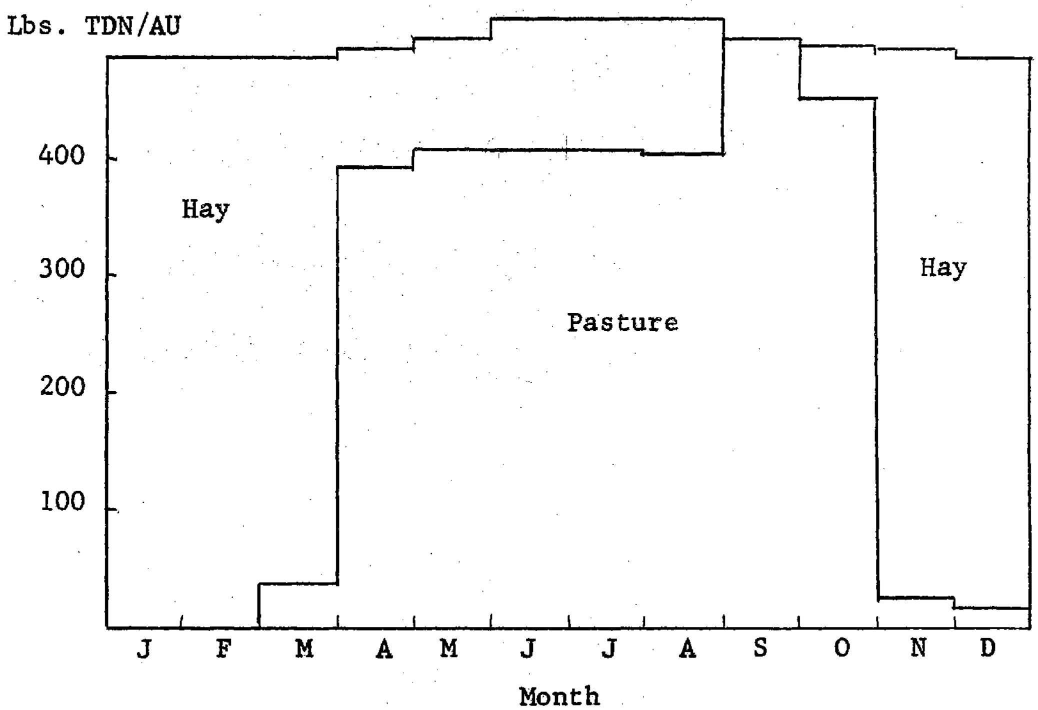

Figure 12. Case 13

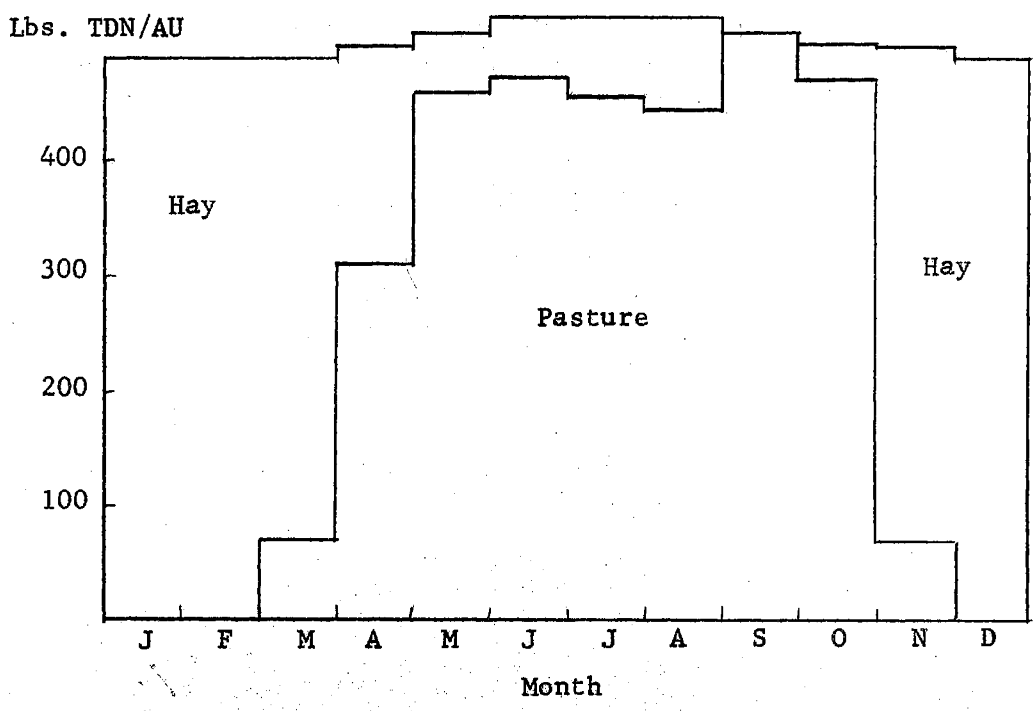

Figure 13. Case 21

The pasture yield and hay feeding patterns for this program are presented in Figure 14. Substantial amounts of hay must be fed during the summer months. Pasture yields are fairly well distributed between March and November, with all TDN being provided by pasture in September.

The instability of all factors in this program is due to the cost change applied to the native pasture. This would not effect the reliability of this program from the economic standpoint. Slight variations in input costs would simply re-introduce native pasture as a substitute for Johnson grass pasture. All activities enter at levels which are reasonable when considering the costs of establishing and maintaining them.

This case is highly desirable from the nutritional standpoint. The dairyman could expect to maintain high milk production throughout the year by feeding the combinations of hay available. Large quantities of alfalfa hay are also available for feeding during the summer months, allowing a smoother transition between the all hay period to the all pasture period.

This program satisfies all economic, botanical and nutritional requirements with the adjustments discussed above. The following cases represent attempts to determine the effects on the total cost and land requirements when some of the important components of this program are denied entry.

Case 38

In this program the input cost of Johnson grass pasture was raised from $6.52 per acre to $9.72 per acre. All other input costs are the same as those used in case 21, that is, native pasture was programmed at an input cost of $5.87 per acre. Total annual cost has increased to $6,122 for the 600,000 pounds of TDN produced, a $240 increase due to the price effect and a \$30 increase due to activity effect over case 21. Total land requirement has increased to 324 acres, the largest requirement for any case programmed under this land ratio situation.

The central effect of a cost increase in Johnson grass pasture is an increase in the proportion of class A_3 land in native pasture and an increase in the total acres required. The dairyman would grow 87 acres of native pasture and 75 acres of Johnson grass in this case. Alfalfa pasture uses all class A_1 land, requiring a total of 86 acres, while 300 tons of hay are harvested from 68 acres of Bermuda grass on class A_2 land. Eight acres of rye-vetch are also grown on the class A_2 land.

Pasture provides all the necessary TDN requirements for the dairy animals in May and September. Very small amounts of hay need to be fed during the rest of the summer as shown in Figure 15. Some TDN is also obtained from pasture throughout the winter months, but large quantities of hay still need to be fed between December and February.

The dairyman using this roughage system would be feeding Bermuda hay during the winter, while the cows are getting some rye-vetch pasture. Some adjustment in the protein content of the concentrate would most likely be necessary to maintain milk production.

By comparing this case with case 21, the full effect of a cost increase for Johnson grass pasture may be analyzed. Native grass pasture substituted for Johnson grass pasture at a ratio of 18 acres of native to 10 acres of Johnson grass, or if the dairyman put one acre of Johnson grass into native pasture, he would add .8 acres of native grass, almost .8 acres of roughage on class A_1 and A_2 land, and \$3.00 per 100 cows to annual cost. For 100 acres an additional quarter-section would be required and the cost would be \$300 more per year.

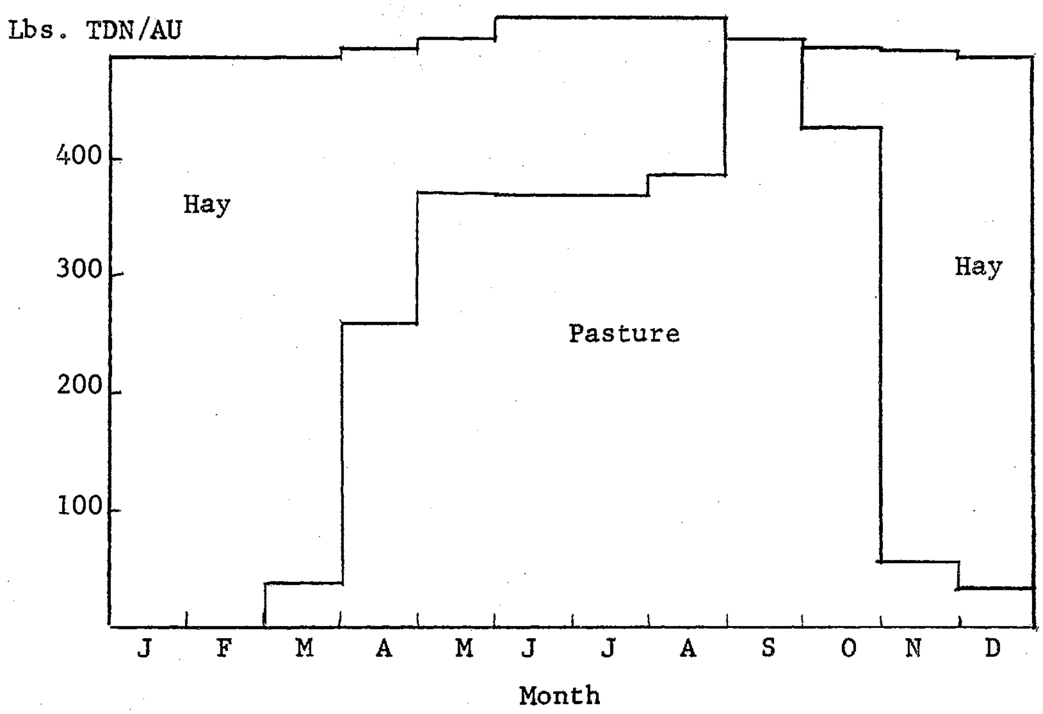

Figure 14. Case 31

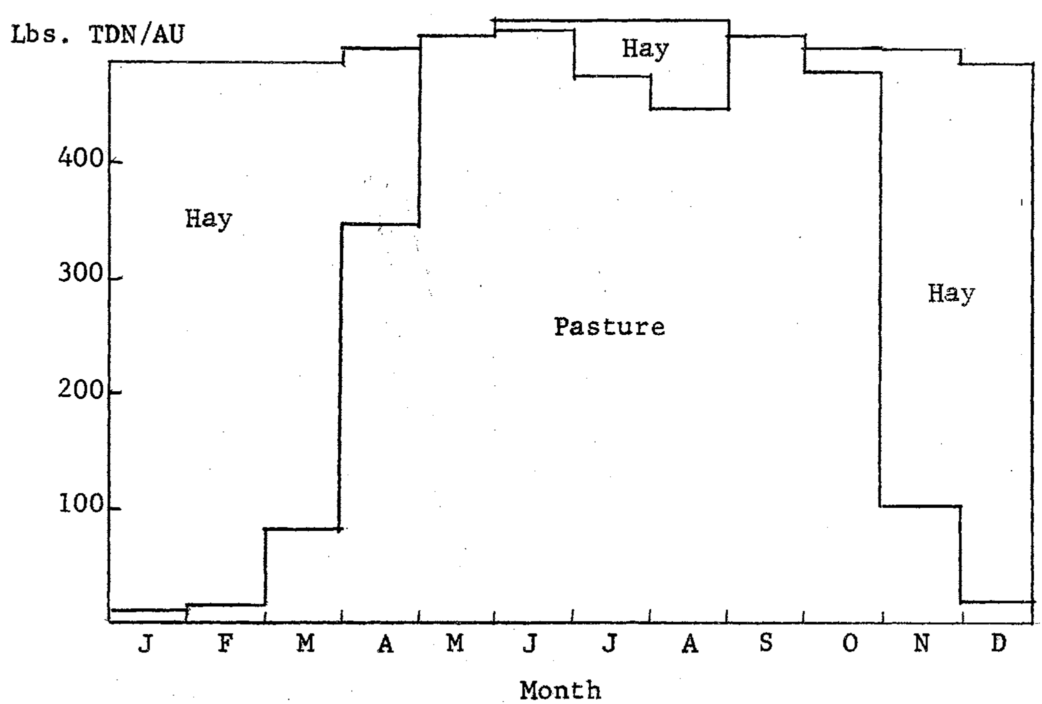

Figure 15. Case 38

All activities are unstable in this case. Additional hay feeding and Bermuda grass pasture would be introduced if any input cost were increased more than 29 cents.

Case 35

In this program the input cost of growing Bermuda hay is raised to a level sufficient to allow millet hay, its closest competitor for class A_2 land, to be harvested. The total annual cost for producing the required 600,000 pounds of TDN is $6,197 which is the highest under this land situation. Forty-six acres of rye-vetch pasture and 26 acres of millet hay would be used by the dairyman on all of the class A_2 land. Eighteen acres of alfalfa pasture and 63 acres of alfalfa hay would be grown on the class A_1 land, providing 220 tons of high quality hay. Johnson grass is recommended on 152 acres of class A_3 land. This is the only case under this praticular land situation which has no unstable activities.

The distributive pattern of pasture yields and hay feeding is quite uneven as illustrated in Figure 16. No hay feeding is required for May or September, while considerable amounts must be fed during July and August, and the winter months. Pasture is available all year, but not in very large quantities during January and February.

This roughage program provides the required TDN with variety, high quality and stability. Variety is due to several types of pasture and hay feeding activities available at all seasons of the year. High quality is derived from the extensive quantities of legume hay and pasture available throughout the year, and stability is due to the variety and sizes of the recommended activities.

Results for Land Ratios $1A_1$: $2.37A_2$: $7.20A_3$

This land situation is characteristic of Lincoln County farms. It indicates an abundance of native pasture land and a very limited amount of land suitable for alfalfa. A typical farm situation with these land ratios would include 48 acres of land suitable for alfalfa (A_1), 115 acres of land suitable for other crops (A_2) and 344 acres of land suitable for native pasture (A_3). The average number of acres for all surveyed farms in this category was 507. The results presented in Table XI are applicable to farms having land ratios approximately the same as those indicated above.

Case 5

The basic program for this land situation, using all costs shown in Table VII provides the required 600,000 pounds of TDN for \$5,555, and has the smallest land requirement of all cases. At a price of \$11.56 per 1,000 TDN, 167 tons of TDN in the form of hay would be purchased by the dairyman. This is equivalent to 332 tons of alfalfa at \$11.62 per ton or 321 tons of native hay at \$12.04 per ton. (See Table IX.)

Thirty-eight acres of rye grass pasture, 16 acres of alfalfa pasture and 112 acres of Johnson grass pasture provide all roughage other than hay. Each activity in this program has a shadow price more than one dollar above or below the input cost, and therefore, is relatively stable.

Pasture yields are quite low in the spring and hay must be fed in every month except September. The distribution of hay feeding and pasture yields is illustrated in Figure 17.

TABLE XI

PROGRAMMED RESULTS FOR LAND RATIOS $1A_1$: $2.37A_2$: $7.20A_3$, PROVIDING THE LEAST COST ANNUAL ROUGHAGE REQUIREMENT FOR 100 ANIMAL UNITS

	Case 5			Case 10			Case 22			Case 28		
Activity	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons
A_1 Land												
Alfalfa Pasture	No	16		No	27		No	0		No	34	
Grow Alfalfa Hay	No	0	0	No	0	0	No	28	98	Yes	0	0
Grow Sudan Hay	No	0	0	No	0	0	No	0	0	No	0	0
A_2 Land												
Rye Grass Pasture	No	38		No	0		Yes	0		Yes	0	
Rye-Vetch Pasture	No	0		No	0		No	0		No	0	
Grow Bermuda Hay	No	0	0	No	65[b]	286	No	66	291	No	81	357
Grow Millet Hay	No	0	0	No	0	0	No	0	0	No	0	0
A_3 Land												
Johnson Grass Pasture	No	112		No	146		No	143[b]		No	80	
Native Pasture	No	0		No	0		No	56[bc]		No	163[b]	
Grow Native Hay	No	0	0	No	49[b]	82	Yes	0	0	Yes	0	0
Buy Hat at:[a]												
$11.56/1,000 TDN	No		167	Yes		0	Yes		0	Yes		0
$13.28/1,000 TDN	No		0	Yes		0	Yes		0	Yes		0
$14.27/1,000 TDN	No		0	No		0	No		0	No		0
Total Acres		166			287			293			358	
Total Cost		$5,555[d]			$5,943			$6,047			$6,090	

(Continued)

TABLE XI (Continued)

Activity	Case 25 Activity Denied?	Case 25 Acres	Case 25 Tons	Case 29 Activity Denied?	Case 29 Acres	Case 29 Tons	Case 27 Activity Denied?	Case 27 Acres	Case 27 Tons
A_1 Land									
Alfalfa Pasture	No	21[b]		No	0		No	0	
Grow Alfalfa Hay	No	0	0	No	41	143	Yes	0	0
Grow Sudan Hay	No	0	0	No	0	0	No	46	112
A_2 Land									
Rye Grass Pasture	Yes	0		Yes	0		Yes	0	
Rye-Vetch Pasture	No	0		No	29[c]		No	22[b]	
Grow Bermuda Hay	No	50	220	Yes	0	0	Yes	0	0
Grow Millet Hay	No	0	0	No	70[c]	143	No	88[c]	180
A_3 Land									
Johnson Grass Pasture	No	150[bc]		No	84[c]		No	62	
Native Pasture	Yes	0		No	210[c]		No	268[b]	
Grow Native Hay	Yes	0	0	Yes	0	0	Yes	0	0
Buy Hay at:[a]									
\$11.56/1,000 TDN	Yes		0	Yes		0	Yes		0
\$13.28/1,000 TDN	Yes		0	Yes		0	Yes		0
\$14.27/1,000 TDN	No		74[b]	Yes		0	Yes		0
Total Acres		221			398			486	
Total Cost		\$6,163[d]			\$6,719			\$6,973	

(Footnotes continued)

TABLE XI (Continued)

[a]See Table VIII and IX for the per ton cost and tons of hay which would be purchased at each of the given costs per 1,000 pounds of TDN.

[b]Indicates that the cost of the activity is within one dollar of the upper bound of the shadow price, implying relative instability in the optimal solution.

[c]Indicates that the cost of the activity is within one dollar of the lower bound of the shadow price, implying relative instability in the optimal solution.

[d]Total cost includes storage, spoilage, loss and handling charge for purchased hay, or approximately $1.20 per 1,000 pounds of TDN added to the purchase price at the farm gate to obtain cost at cow's mouth.

This roughage program is similar to case 1, and therefore presents similar problems which are: (1) effect of price variability in hay buying, (2) difficulty in establishing and maintaining Johnson grass on class A_3 land, (3) difficulty in getting palatable roughage from rye grass, and (4) uneven distribution of available protein. Each of these problems must be considered by the decision maker before he would commit his resources to this roughage program. The possible alternatives and adjustments under this land situation are many and varied as under the previous land situation. Some can be determined by additional programming while others may be estimated through a logical analysis. The following cases represent an attempt to study the alternatives and adjustments by these methods.

Case 10

When the cost of purchased hay is $14.27 per 1,000 TDN, no hay is bought, total annual cost for the 600,000 pounds of TDN produced is $5,943, and total land required is 287 acres.

One hundred forty six acres of class A_3 land is used for Johnson grass while 49 acres of class A_3 land is used for harvesting native grass hay. Twenty-seven acres of alfalfa pasture use all the class A_1 land and 65 acres of Bermuda grass produce 286 tons of hay on the class A_2 land.

The hay growing activities are unstable in this program. An increase in the input cost of either Bermuda or native hay of more than 92 cents would bring the hay buying activity into the optimal solution.

The combination of Johnson grass and alfalfa pasture provide an uneven distribution of available TDN between March and November.

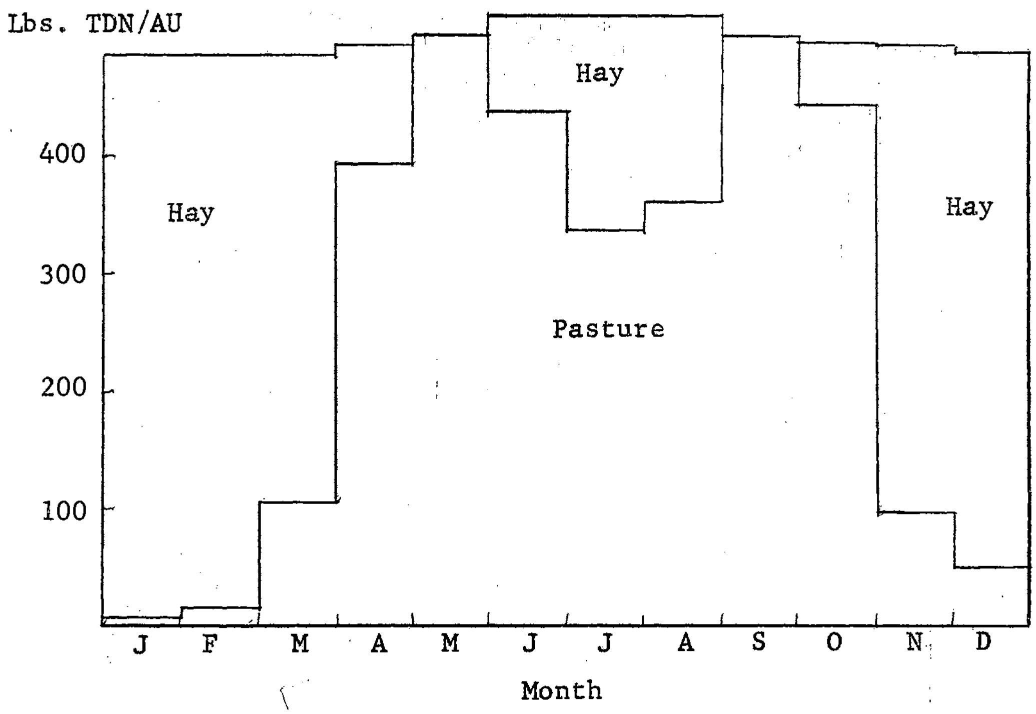

Figure 16. Case 35

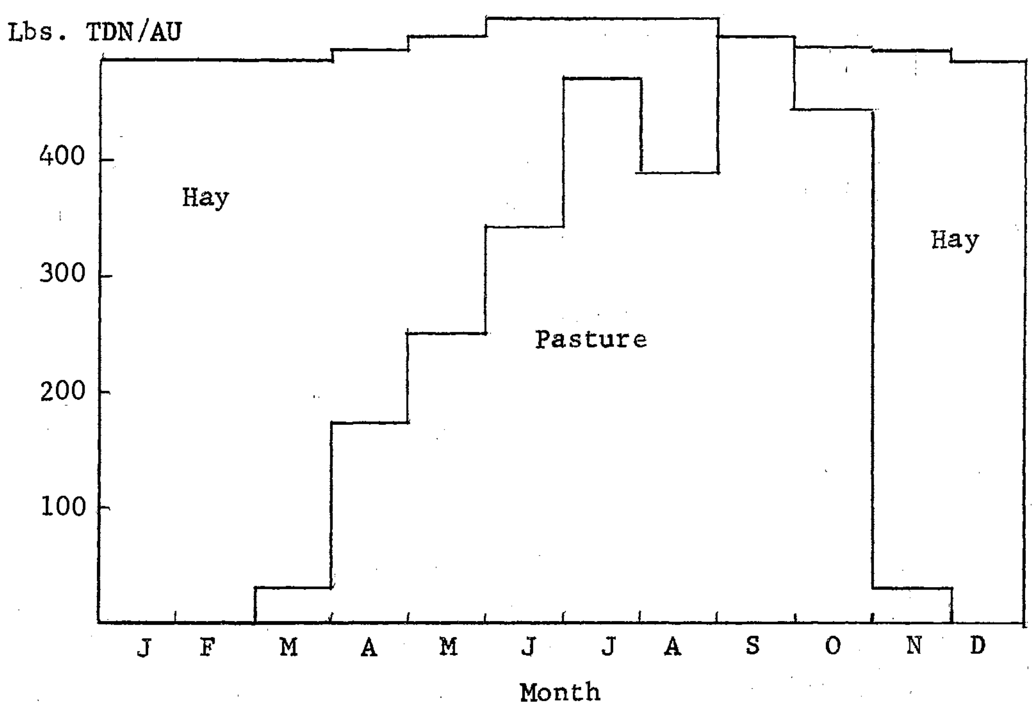

Figure 17. Case 5

Substantial quantities of grass hay must be fed between March and July. The dairy animals must also depend on grass hay between December and February as shown in Figure 18. This is a major weakness since no legume is available for three to four months of the year. Further adjustments in the farm organization are necessary to alleviate this problem.

Case 22

When the input costs of growing native hay and rye grass pasture are raised to a sufficient level to deny entry of these activities, native pasture and alfalfa hay enter the roughage program. Total annual cost for this program is \$6,047 and total land requirement is 293 acres as shown in Table XI. This is a cost increase of \$104 over case 10 and \$492 over case 5. Johnson grass and native grass pasture together require 199 acres of class A_3 land. Bermuda grass requires 66 acres of class A_2 land producing 291 tons of hay. Twenty-eight acres of alfalfa would be grown by the dairyman on the class A_1 land providing 98 tons of hay.

Both pasture activities are relatively unstable in this program. An increase in the input cost of Johnson grass pasture would introduce alfalfa pasture into the solution, while an increase in the input cost of native grass pasture would bring an alfalfa hay feeding activity into the program.

This program has characteristically low spring and summer pasture yields, while nearly all TDN requirements are provided by pasture during September and October. Considerable amounts of hay must be fed between November and August as illustrated in Figure 19. Some variety is available in this roughage system, especially in feeding hay. It is still necessary to feed large amounts of Bermuda grass hay, but the 98 tons of

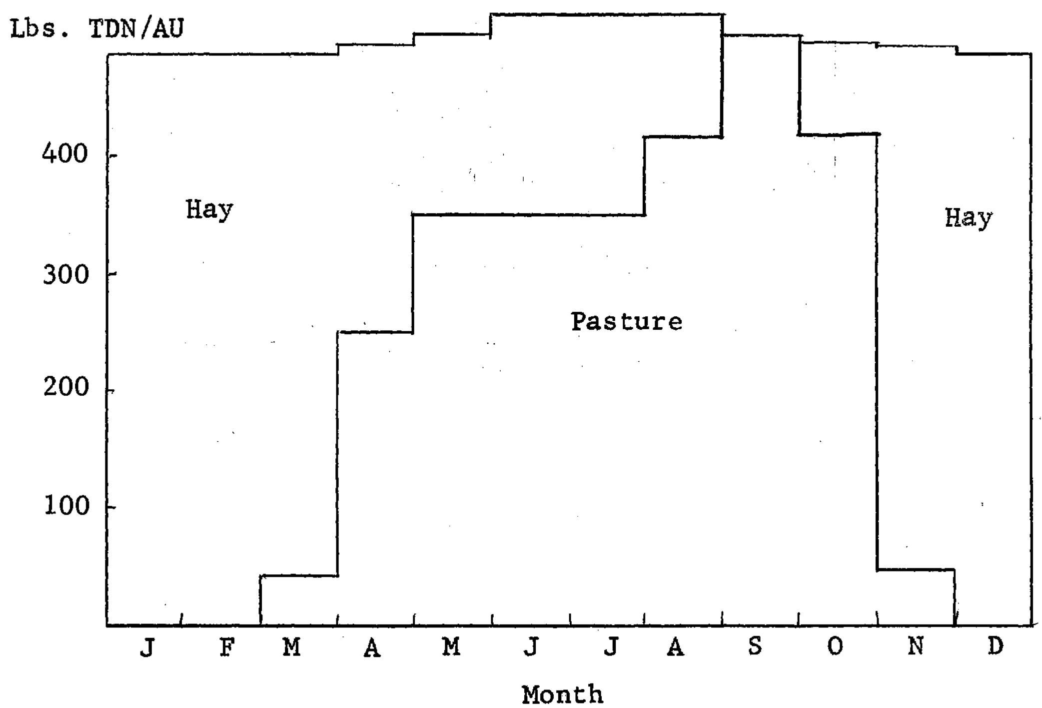

Figure 18. Case 10

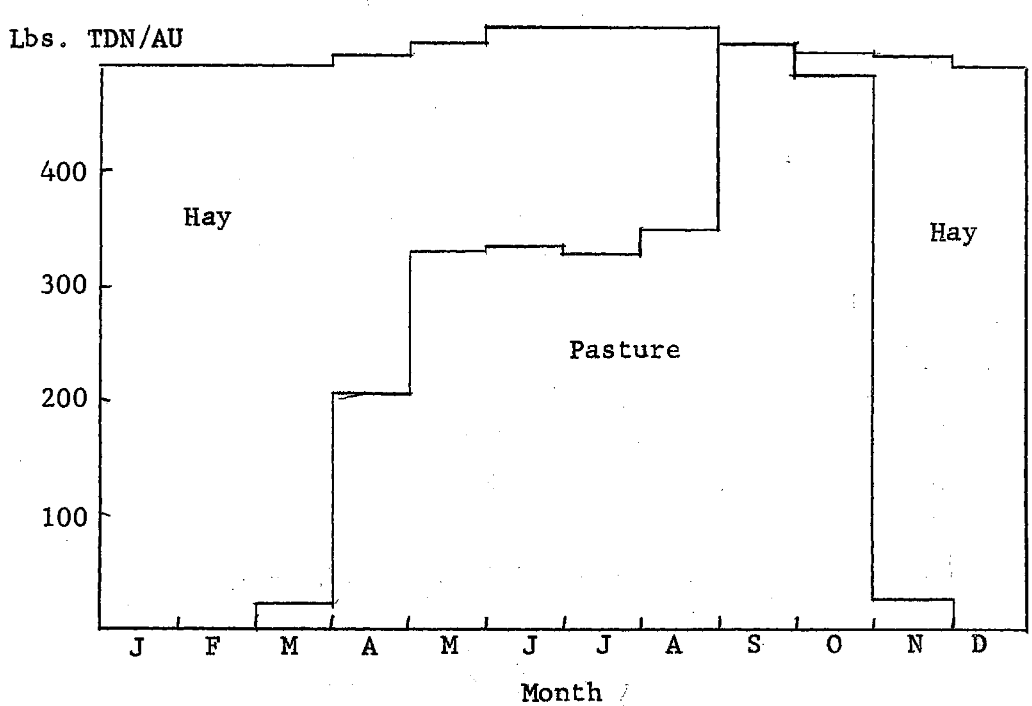

Figure 19. Case 22

alfalfa hay provide the necessary high quality legume roughage. The following case brings alfalfa pasture back into the roughage program as a substitute for alfalfa hay on the class A_1 land.

Case 28

When the input cost of growing alfalfa hay is raised enough to deny entry of this activity, the alfalfa land is used for pasture and the total acreage increases 22 per cent over case 22. Total annual cost increases to $6,090 while total land required increases to 358 acres as indicated in Table XI. Native grass pasture requires 163 acres of the class A_3 land. Johnson grass pasture requires 80 acres of the class A_3 land, while 34 acres of alfalfa pasture use all class A_1 land. Eighty-one acres of Bermuda grass use all class A_2 land producing 357 tons of hay.

Native grass pasture is the only unstable activity in this program. An input cost increase of at least 45 cents would be required to replace it with a hay buying activity.

The distributive pattern of pasture yield and hay feeding in terms of TDN per month is illustrated in Figure 20. Pasture yields are fairly well distributed with June and September the best months. Bermuda hay is the only source of roughage during December, January and February. Some pasture can be expected in March, April and November, but heavy hay feeding is still required during these periods. Bermuda grass hay is not conducive to high milk production, therefore the concentrate ration should be adjusted during the winter hay feeding period to higher protein levels. During the summer a variety of pasture roughages are available permitting a lower protein concentrate ration to be used. The next four cases were programmed to determine what adjustments might be made within the roughage program to alleviate this problem.

Case 25

When the input cost of native pasture is increased by 71 cents, dairymen are willing to pay at least $14.27 per 1,000 TDN in order to buy hay and reduce the total land requirement. Total cost increases to $6,163 and total land required decreases to 221 acres. Total land recommended for Johnson grass increases to 150 acres. Alfalfa pasture requires 21 acres of class A_1 land, while 50 acres of Bermuda grass are harvested from the class A_2 land providing 220 tons of hay.

Johnson grass pasture, alfalfa pasture and hay buying are unstable activities in this program as shown in Table XI. Johnson grass pasture would be partially replaced by either native grass pasture or feeding alfalfa hay. Alfalfa pasture would be replaced by feeding alfalfa hay, and buying hay would be partially replaced by feeding alfalfa hay.

The pasture yield distribution as shown in Figure 21 is quite uneven throughout the year. It is necessary to feed hay in every month except September, when pasture provides the required level of TDN. Considerable amounts of hay must be fed between May and August. With little variety in available roughage the dairyman is very limited in his feeding practices, unless alfalfa hay can be purchased at $14.35 per ton.

Case 29

Rye grass pasture, hay buying, growing Bermuda hay and growing native hay activities are denied entry in this case. The class A_2 land is used for rye-vetch pasture and millet hay, while the class A_3 land is

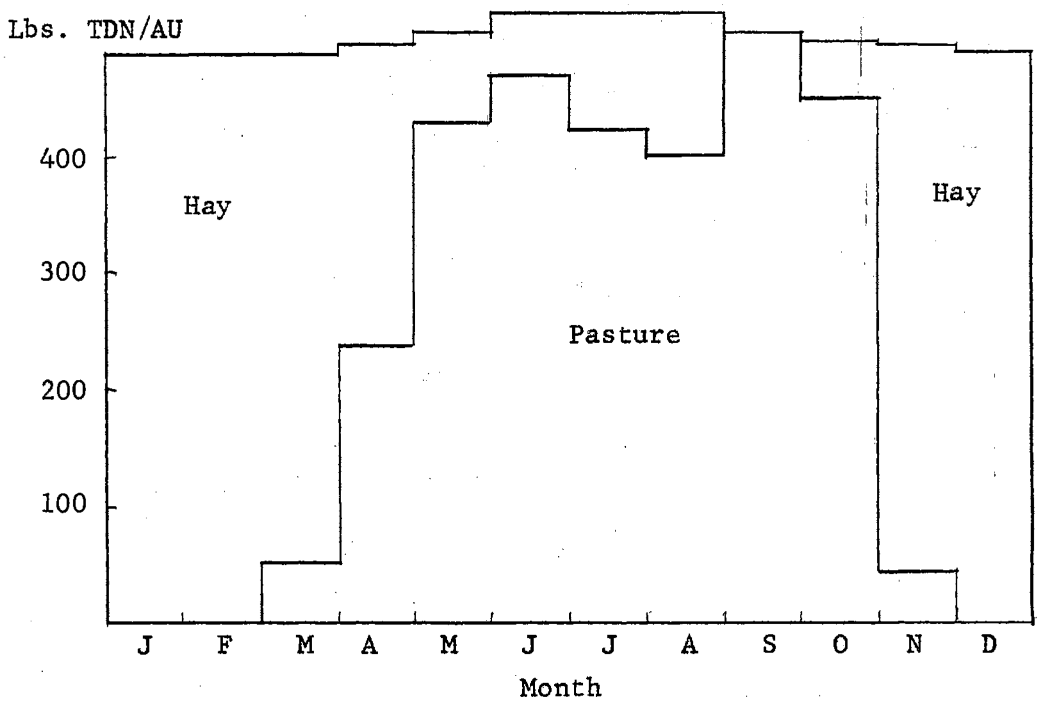

Figure 20. Case 28

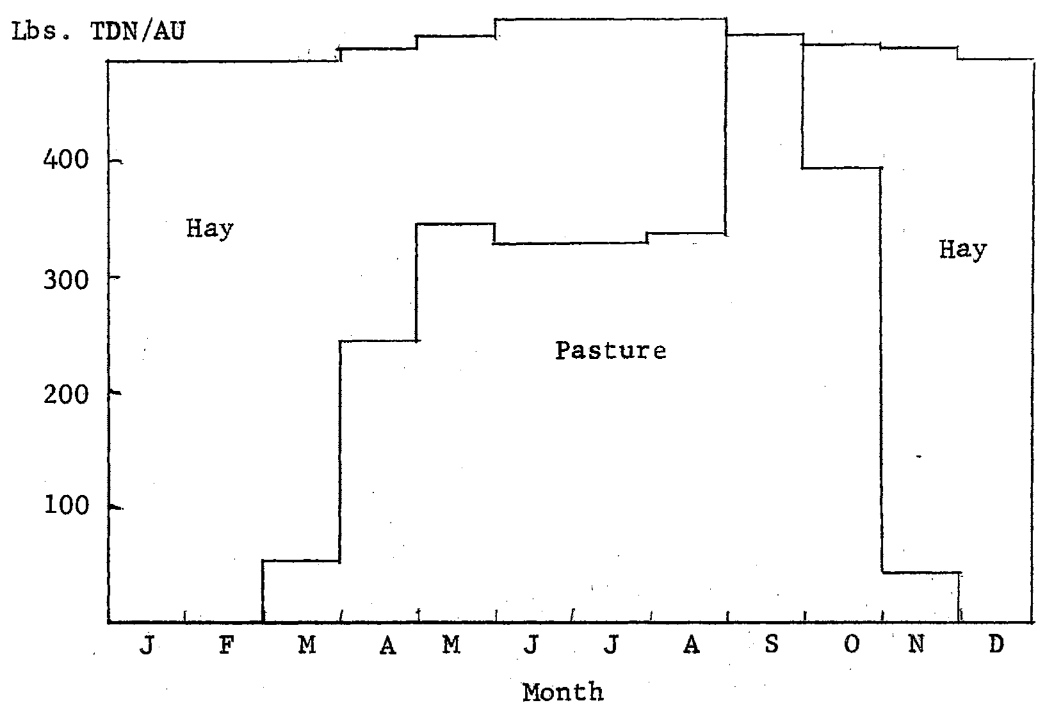

Figure 21. Case 25

used primarily for native grass pasture. Forty-one acres of alfalfa are grown on the class A_1 land, producing 143 tons of hay. Seventy acres of millet produce 143 tons of hay on the class A_2 land while 29 acres of rye-vetch pasture are grown on the remaining class A_2 land. Two hundred and ten acres of native grass pasture and 84 acres of Johnson grass pasture are grown on the A_3 land. Total annual cost is \$6,719, or \$67.19 per animal unit, while total land required is 398 acres.

The lower bound of the shadow price is within one dollar of the input cost for the Johnson grass, native pasture, rye-vetch pasture and millet hay making these activities unstable.

The distributive pattern of total pasture yields and hay feeding is illustrated in Figure 22. Pasture yields are exceptionally high during May and June, declining somewhat in July and August and reaching their maximum again in September and October. Pasture is also available between November and March reducing the total amount of hay feeding during these periods. Some hay must be fed during the summer months, but pasture still provides most of the required TDN throughout the year.

This program has many favorable characteristics. The unstable activities are unstable only with respect to their lower bounds and would be replaced with alfalfa hay, an activity already in the program. There is considerable variety in available types of pasture during the pasture season. There is also variety in the types of hay which may be fed. The dairyman would not have to rely on only one source of roughage. The quality of hay available would support high milk production during the off-pasture season and would also supplement the all grass and vetch pasture during the pasture season.

Further adjustments in input costs and activities would be of an experimental nature to determine the stability of this program and to find any other alternatives.

Case 27

When Sudan hay is substituted for alfalfa hay, it is grown on 46 acres of class A_1 land and produces 112 tons of hay which is less and lower quality hay than would be produced by alfalfa. Twenty-two acres of rye-vetch pasture are grown on the class A_2 land while millet produces 180 tons of hay on 88 acres of class A_2 land. Johnson grass pasture would be grown on 62 acres while native pasture would be grown on 268 acres of the class A_3 land. Total annual cost increases to $6,973 and total land requirement increases to 486 acres.

The total pasture yields are very high during May, June, September and October as indicated in Figure 23. Some hay must be fed during July and August. The heaviest hay feeding period is between November and March, even though some rye-vetch pasture is available in this period.

The native and rye-vetch pastures are unstable activities in this roughage system. An increase of at least 74 cents in the cost of either native or rye-vetch pasture would introduce alfalfa hay into the program. An input cost decrease of at least 74 cents would introduce Bermuda hay into the program as a substitute for millet hay.

Results for Land Ratios $1A_1$: $1A_2$: $1A_3$

This land situation was approximated by eight farms in the area of this study. It implies that the dairy farmer would have equal quantities of each type of land available for use in the dairy enterprise. If the

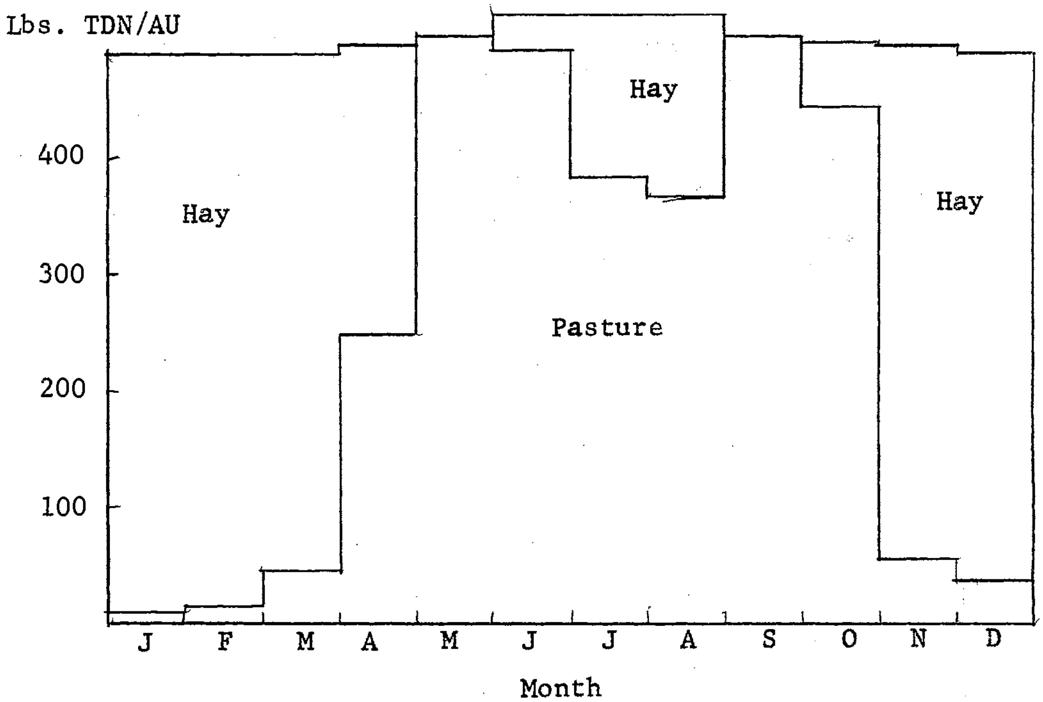

Figure 22. Case 29

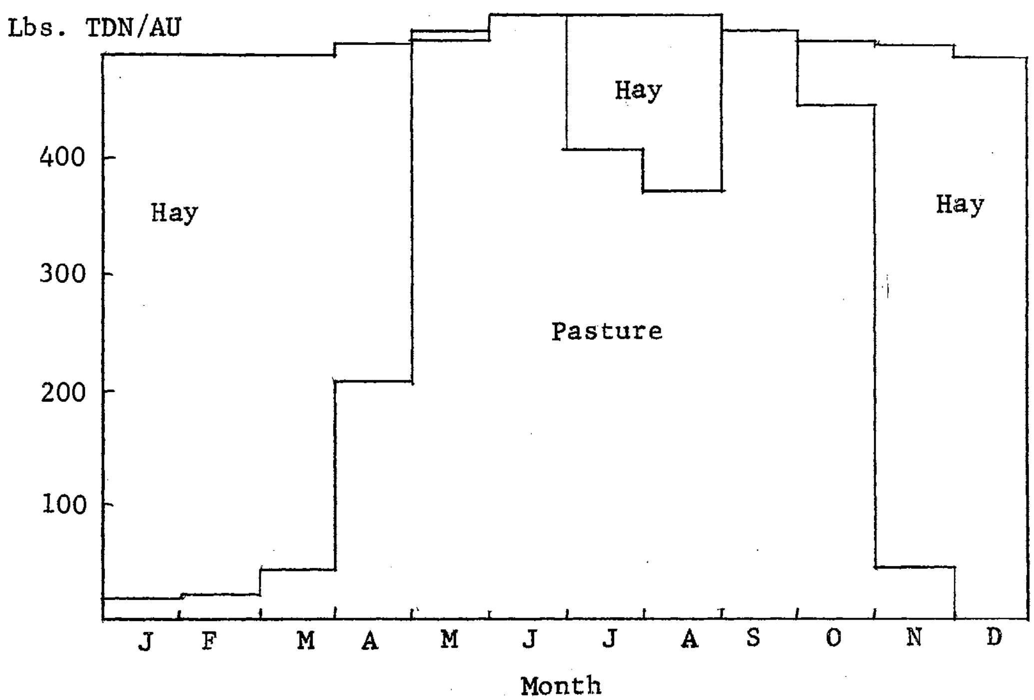

Figure 23. Case 27

land ratios on the farm corresponded to the above, the following results would be applicable.

Case 18

All input costs are those presented in Table VII. Total annual cost for the 600,000 pounds of TDN is \$5,635 and total land required is 233 acres, as indicated in Table XII.

Seventy-eight acres of class A_1 land are used for alfalfa pasture. Johnson grass pasture is grown on 78 acres of class A_3 land. Twelve acres of Bermuda grass pasture, 35 acres of rye-vetch pasture and 21 acres of rye grass pasture use 68 acres of class A_2 land. Nine acres of Bermuda grass produces 40 tons of hay on the rest of the class A_2 land. One hundred tons of TDN in the form of hay would be purchased in this program at a cost of \$11.56 per 1,000 TDN. All activities are unstable with respect to both the upper and lower bounds of the shadow price, except growing Bermuda grass hay and rye grass pasture.

The distribution of total pasture yields and hay feeding in terms of TDN per month is illustrated in Figure 24. Pasture provides nearly all TDN required for five full months: May, June, July, September and October. The amounts of hay which must be fed in the other periods of the year are substantially reduced by the presence of some pasture in these periods. The variety of pastures available are important in this case, since one may be substituted for another as yields vary. There is also an opportunity for smooth transition of grazing from one pasture to the next throughout the season. The dairyman would have to rely heavily on all grass hay for several months of the year. Some rye-vetch pasture is available during this time, but not in quantities sufficient to maintain

TABLE XII

PROGRAMMED RESULTS FOR LAND RATIOS $1A_1$: $1A_2$: $1A_3$ and OA_1: $1A_2$: $2.98A_3$, PROVIDING THE LEAST COST ANNUAL ROUGHAGE REQUIREMENTS FOR 100 ANIMAL UNITS

	$1A_1$: $1A_2$: $1A_3$						OA_1: $1A_2$: $2.98A_3$					
	Case 18			Case 41			Case 9			Case 37		
Activity	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons	Activity Denied?	Acres	Tons
A_1 Land												
Alfalfa Pasture	No	78[bc]		No	89							
A_2 Land												
Bermuda Pasture	No	12[bc]		No	0		No	0		No	0	
Rye-Vetch Pasture	No	35[bc]		No	0		No	0		No	0	
Rye Grass Pasture	No	21		No	16[b]		No	15		Yes	0	
Vetch-Oats Wheat Pasture	No	0		No	0		No	35		Yes	0	
Grow Bermuda Hay	No	9	40	No	73[b]	322	No	0	0	No	66	291
A_3 Land												
Johnson Grass Pasture	No	78[bc]		No	89		No	148		No	143[b]	
Native Pasture	No	0		No	0		No	0		No	56[c]	
Buy Hay at:[a]												
$11.56/1,000 TDN	No		100[bc]	Yes		0	No		99	Yes		0
$13.28/1,000 TDN	No			Yes		0	No		0	Yes		0
$14.27/1,000 TDN	No			No		0	No		0	No		49
Total Acres		233			267			198			265	
Total Cost		$5,635[d]			$5,705			$5,997[d]			$6,048[d]	

(Footnotes continued)

TABLE XII (Continued)

[a]See Table VIII and IX for the per ton cost and tons of hay which would be purchased at each of the given costs per 1,000 pounds of TDN.

[b]Indicates that the cost of the activity is within one dollar of the upper bound of the shadow price, implying relative instability in the optimal solution.

[c]Indicates that the cost of the activity is within one dollar of the lower bound of the shadow price, implying relative instability in the optimal solution.

[d]Total cost includes storage, spoilage, loss and handling charge for purchased hay, or approximately $1.20 per 1,000 pounds of TDN added to the purchase price at the farm gate to obtain cost at cow's mouth.

milk production at a level which would be forthcoming from an all legume roughage. The primary weakness of this program would be the uncertainty of the low hay purchasing price. The following case illustrates the result of a price change for this activity.

Case 41

According to this case, when the cost of purchased hay approaches \$15.00 per 1,000 TDN, it is no longer feasible to buy it. Bermuda hay is grown on A_2 land to replace rye-vetch and Bermuda pasture. Total cost is \$5,705 for the 100 animal units and total land required is 267 acres, a 15 per cent increase over case 18. Johnson grass pasture requires 89 acres of the class A_3 land while alfalfa pasture uses the same quantity of class A_1 land. Sixteen acres of rye grass pasture enter the program, using class A_2 land. Three hundred and twenty-two tons of Bermuda grass hay are harvested from 73 acres of A_2 land, replacing the Bermuda and rye-vetch pasture in case 18. Rye grass pasture and growing Bermuda grass hay are the only unstable activities in this program.

The distribution of pasture yields is uneven. Yields build up to high levels in the late summer and early fall. Hay is the only source of roughage during the months of December, January and February, while almost no hay is fed in July, September and October. These distributive patterns are illustrated in Figure 25.

The dairyman using this program would not have to depend on purchased hay as a primary source of roughage on his farm. A variety of pastures are available, but the dairyman must feed Bermuda grass hay during the off-pasture season. This again is not conductive to high milk production, especially since no rye-vetch pasture is available as in case 18.

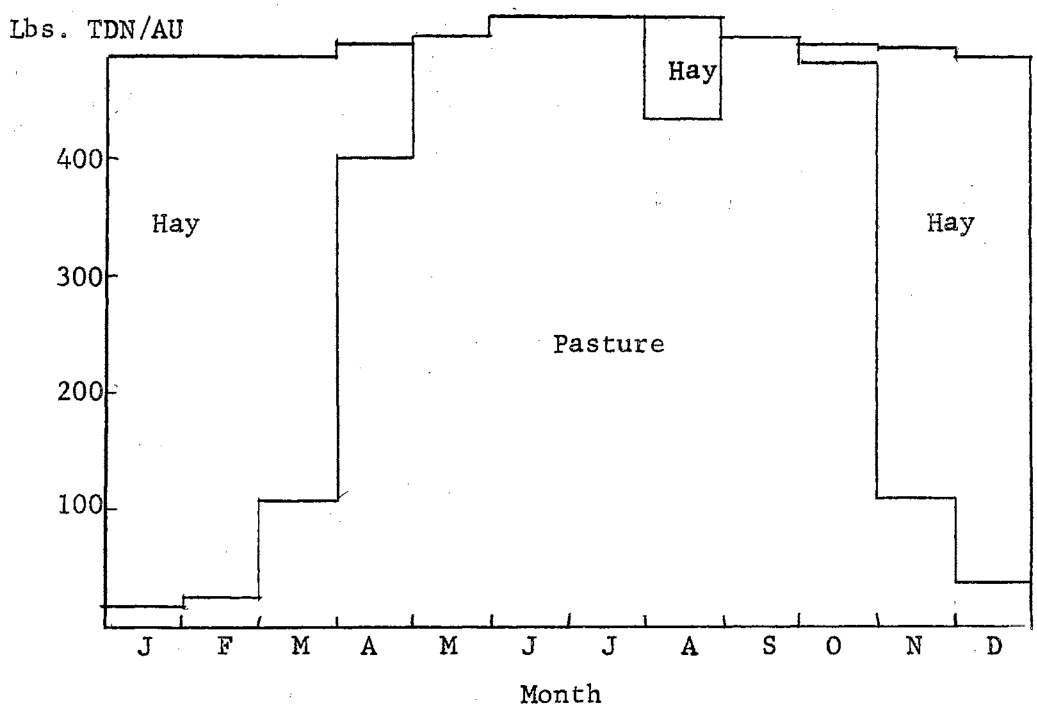

Figure 24. Case 18

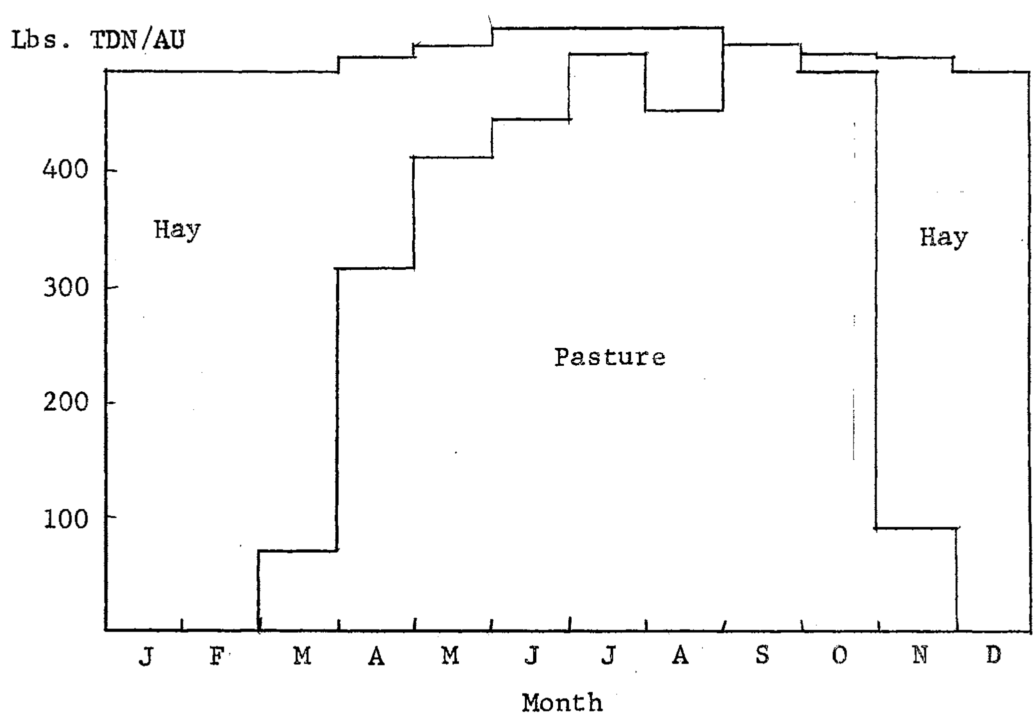

Figure 25. Case 41

Results for Land Ratios $0A_1$: $1A_2$: $2.98A_3$

The dairyman who finds himself in this particular land situation has no land available for alfalfa. Under a typical situation he would have approximately 100 acres of land suitable for roughage crops on class A_2 land. He would also have approximately 298 acres of land suitable for native pasture or Johnson grass. This would provide a total of 398 acres of available land for use in the dairy enterprise. If the dairyman, upon determining his own particular land situation, finds that his farm fits the above category, he should consider the following results applicable.

Case 9

All input costs used in this program are those presented in Table VII. The total annual cost, as shown in Table XII, is $5,997, and total land required, 198 acres. Johnson grass pasture requires 148 acres of the class A_3 land. Fifteen acres of rye grass pasture and 35 acres of vetch-oats-wheat pasture are grown on the class A_2 land. Ninety-nine tons of TDN in the form of hay is purchased at $11.56 per 1,000 TDN. All activities are relatively stable in this program.

Pasture yields during the summer months are somewhat low as illustrated in Figure 26. Hay must be fed in every month except September when all TDN requirements are met by pasture. The vetch-oats-wheat pasture provides some grain roughage during the winter hay feeding period. This improves the overall roughage quality in the winter, which is low because only low quality hay can be purchased at $11.62 per ton.

The following case illustrates the adjustments which would be forthcoming when hay costs more than $11.56 per 1,000 pounds of TDN.

Case 37

In this case rye grass pasture, vetch-oats-wheat pasture and buying hay at \$11.56 and \$13.28 per 1,000 pounds of TDN are denied entry into the roughage program. Bermuda hay is grown on all A_2 land, producing 291 tons on 66 acres. Forty-nine tons of TDN are purchased at a price of \$14.27 per 1,000 TDN. The total annual cost for this program is \$6,048 which represents a \$26 increase due to price effect and a \$25 increase due to activity effect. Total land required is 265 acres, representing a 67 acre increase over case 9 as shown in Table XII. Johnson grass pasture enters this program at about the same level as in case 9, requiring 143 acres of class A_3 land, and 56 acres of native pasture would be used by the dairyman on the class A_3 land. The pasture activities are unstable in this program. A cost increase in the use of Johnson grass pasture or a cost decrease in the use of native grass pasture would change the optimal solution.

The distributive pattern for total pasture yields and hay feeding is illustrated in Figure 27. Hay must be fed every month except September. The heaviest feeding period is between November and March with pasture taking over gradually after the first of April.

In this case, variety in pasture has been sacrificed for variety in hay feeding. The input cost on the purchased hay is the highest price for which it enters the program. The price of \$14.27 per 1,000 TDN would buy alfalfa hay at \$14.35 per ton which would provide the only source of non-grass roughage in the program, and would be necessary to maintain high milk production without adjustments in the non-roughage ration. The nutritional problem may be alleviated by growing and harvesting other

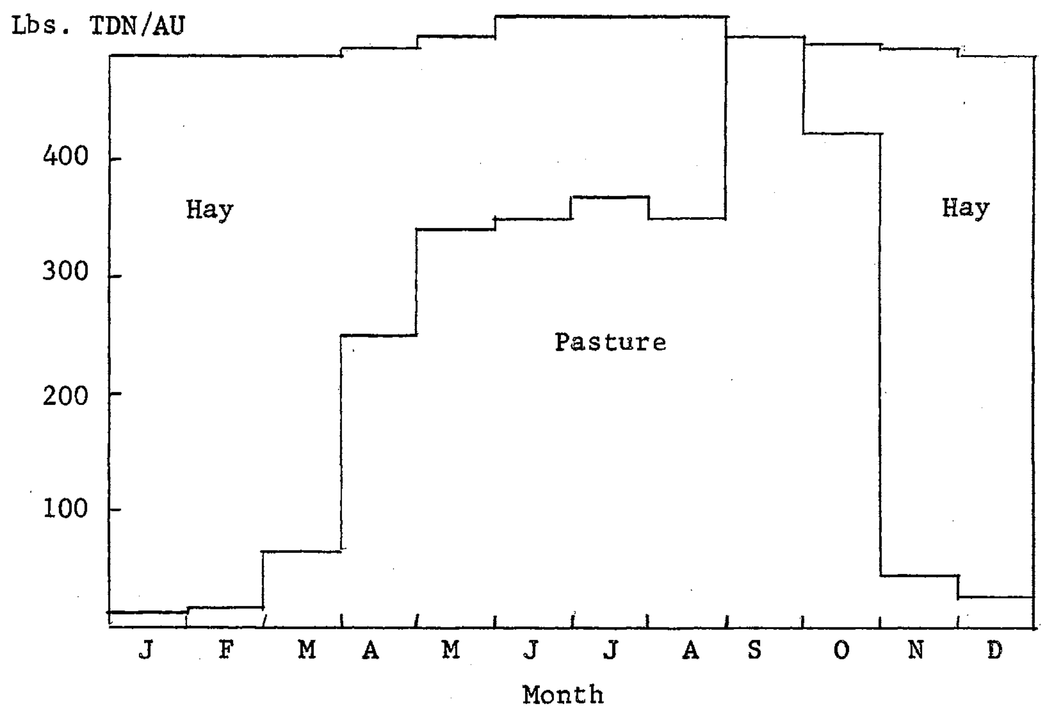

Figure 26. Case 9

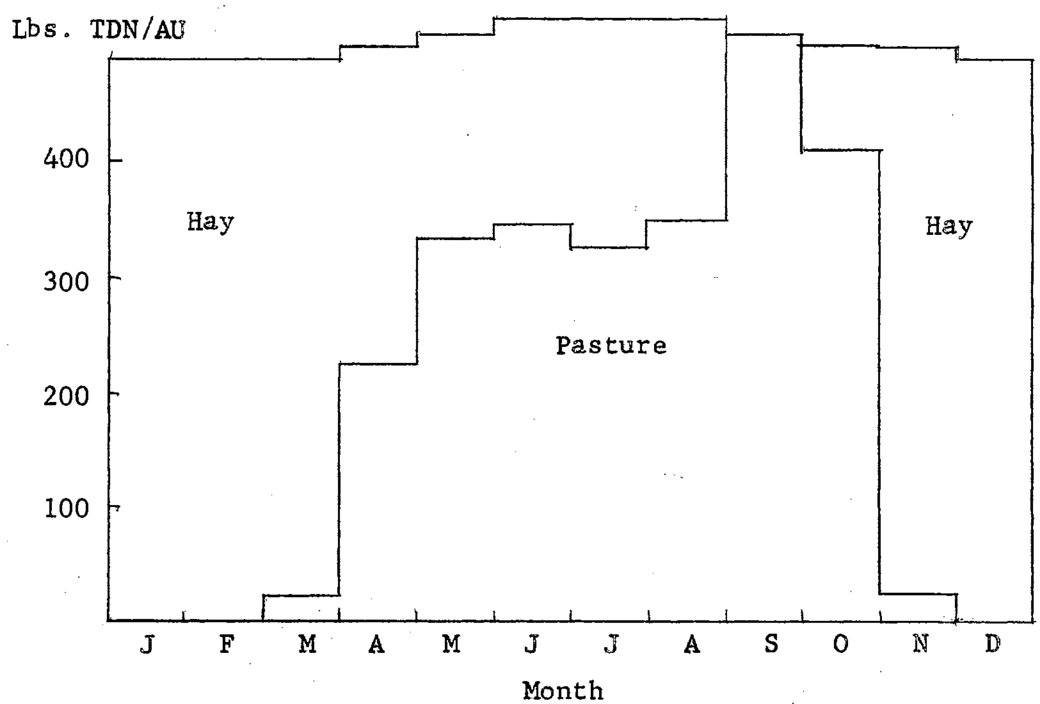

Figure 27. Case 37

types of high quality hay, such as Bermuda-hop clover and cowpea hay, on the class A_2 land when Bermuda and native hay are denied. This adds considerably more to total cost and land requirement and therefore did not appear in the program results.

CHAPTER V

CONCLUDING ANALYSIS

Chapter IV provides a description and brief discussion of each of the programmed results. Considering each case in a purely theoretical framework permits the researcher to make such statements as, "Case 1 is the least cost method of obtaining roughage." The shortcomings of such outward statements may not be obvious, therefore it is felt that further elaboration of the programmed results are required.

The total cost and acres required per animal unit of all cases presented in Chapter IV are less than the costs and land use of the roughage systems observed on the sample farms. Table XIII summarizes the sample roughage systems and the least cost programmed roughage systems when hay is purchased and when hay is not purchased for each land situation. This table indicates potential savings in roughage production up to $16.63 and 2.86 acres per animal unit, or at least $6.38 and 1.72 acres per animal unit, compared with the sample averages. If no hay is purchased, the dairyman could save up to $13.96 and 1.38 acres per animal unit or at least $8.00 and .95 acres per animal unit, compared to the sample averages.

The above comparisons are based on the costs, yields and levels of feeding used in the programming analysis. Figures 28 through 31 illustrate the distributive pattern of pasture yields for the sample farms using the program input data. The tables do not correspond to the distribution pattern of consumption presented in Chapter II because an alternate grouping of alternatives is used. Computations corresponding to Figures 28 through 31 are presented in Appendix Tables XVII through XXI.

TABLE XIII

SUMMARY OF COSTS AND LAND REQUIREMENT FOR SOME PROGRAMMED RESULTS AND FOR THE SAMPLE

Land Situation	Sample Average		Least Cost With Purchased Hay		Least Cost With No Purchased Hay	
	$/hd.	A./hd.	$/hd.	A./hd.	$/hd.	A./hd.
1	72.00	3.74	55.37	1.80	58.04	2.79
2	72.00	4.06	55.55	1.66	59.43	2.87
3	65.05	4.05	56.35	2.33	57.05	2.67
4	66.35	4.84	59.97	1.98	-	-

The remainder of this chapter is devoted to a discussion of additional aspects of the combined cases in an attempt to tie them together and to determine the combination of roughage sources that best satisfies the objectives of the study. These objectives as set forth in Chapter I are: (1) to provide roughage TDN for the least cost, (2) while utilizing available land, (3) maintaining milk production, and (4) minimizing uncertainty. Each of these objectives will be considered in turn.

Total Cost

Dairymen using the roughage systems presented in Chapter IV would incur less than average roughage production costs because they would be utilizing pasture roughage from permanent types of pasture during the time when pasture yields are maximum, and would feed more hay during the

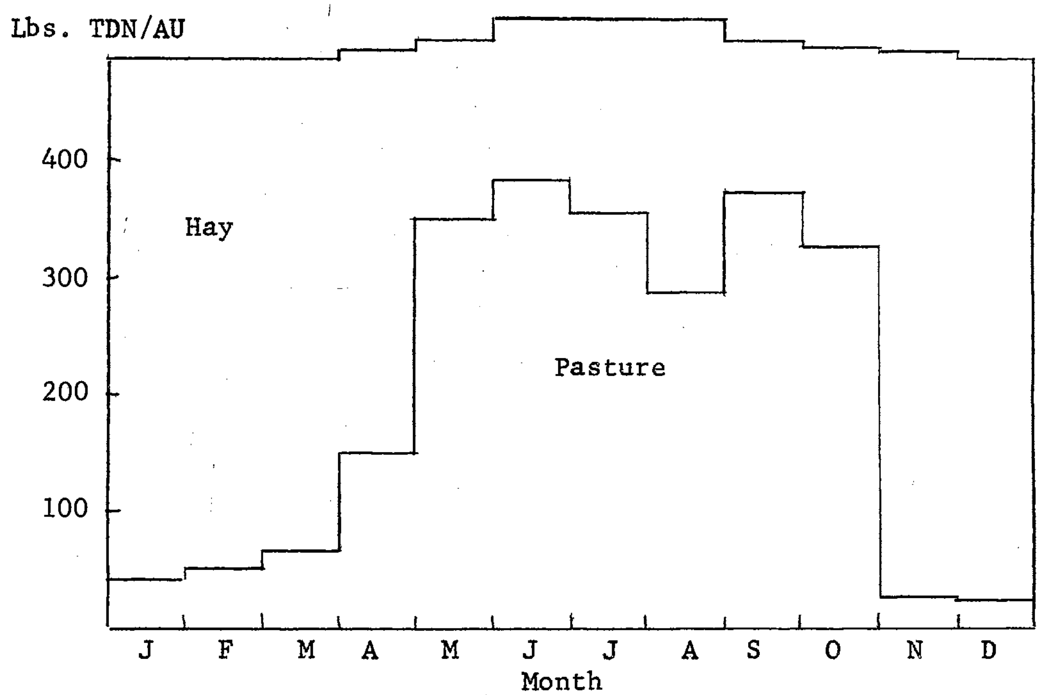

Figure 28. Roughage Distribution, Sample Farms, Land Ratios $1A_1$: $.897A_2$: $1.98A_3$, TC/AU = $72.00, Acres/AU = 3.74

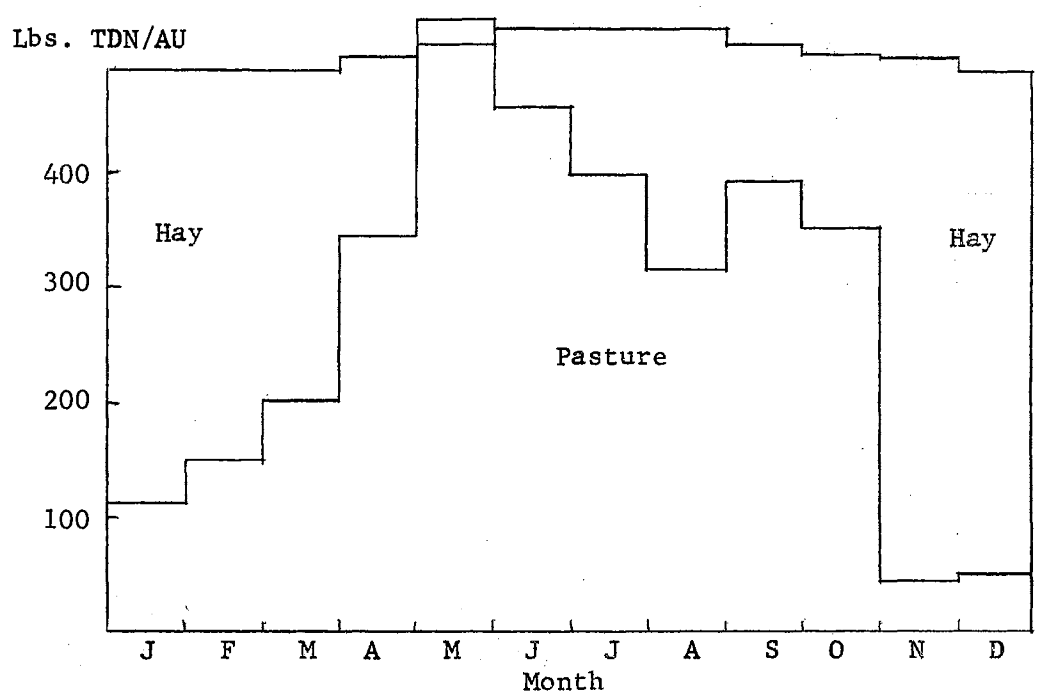

Figure 29. Roughage Distribution, Sample Farms, Land Ratios $1A_1$: $2.37A_2$: $7.20A_3$, TC/AU = $72.00, Acres/AU = 4.08

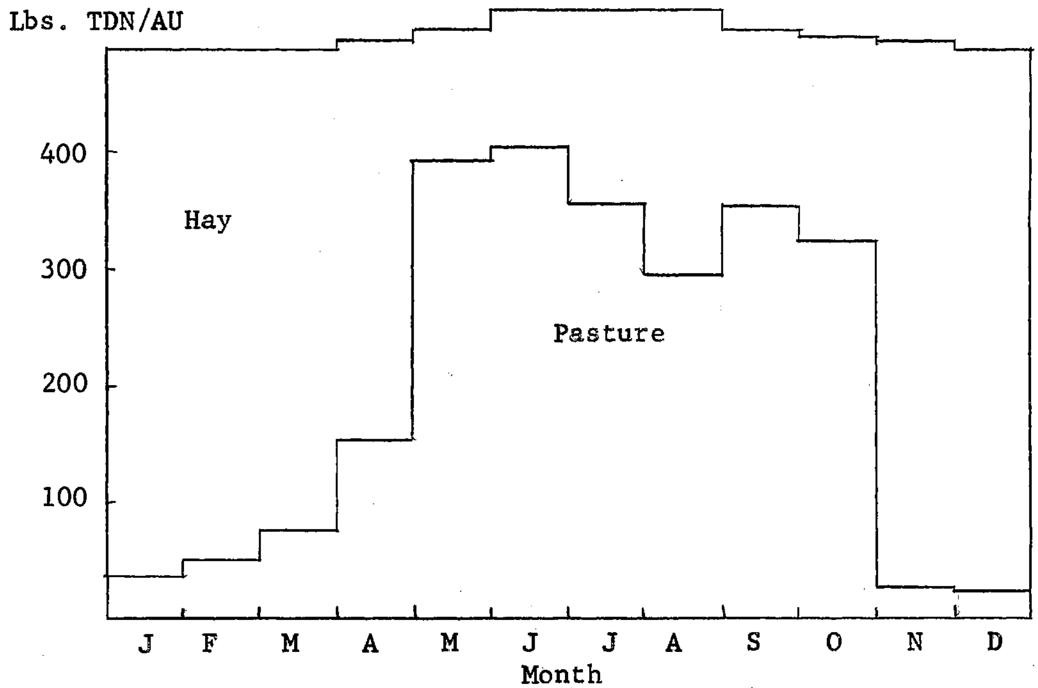

Figure 30. Roughage distribution, Sample Farms, Land Ratios $1A_1$: $1A_2$: $1A_3$, TC/AU = \$65.00, Acres/AU = 4.05

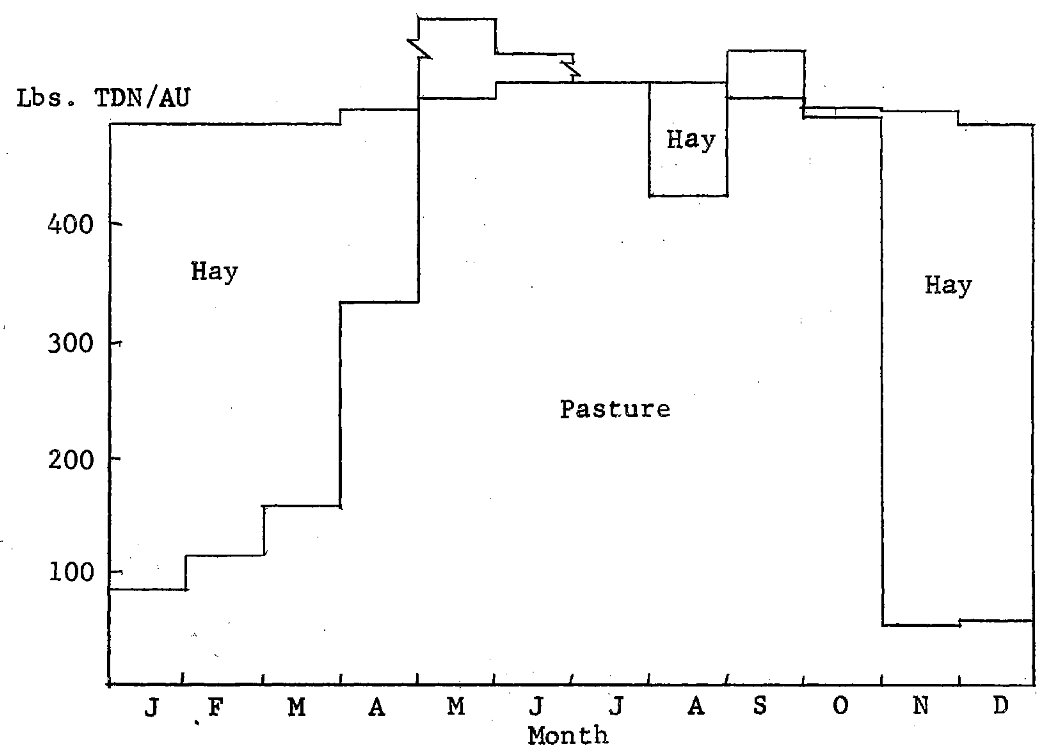

Figure 31. Roughage Distribution, Sample Farms, Land Ratios $0A_1$: $1A_2$: $2.98A_3$, TC/AU = \$66.35, Acres/AU = 4.84

winter rather than use small grain winter pasture. This study does not consider the case where small grain is used as a cash crop in addition to pasture. Some of the low cost solutions depend on an abundant, inexpensive hay supply. Hay may profitably be purchased in most cases only when the market price is less than $14.27 per 1,000 pounds of TDN, otherwise more land should be used to grow and harvest hay on the farm. Limited land availability situations were not studied, and if land were limiting, farmers could afford higher hay prices. Silage was found to be more expensive than any other source of roughage and is not utilized in any of the systems presented in this study.

For farms in the first land situation, it is more profitable to grow hay on the farm when the market price is above $13.28 per 1,000 pounds of TDN. Harvested native, alfalfa and Bermuda hay provide roughage for approximately $1.34 per 1,000 pounds of TDN less than millet hay, and would be grown when market prices are as indicated above.

A low-cost source of grass hay can reduce costs $.95 to $6.60 per cow per year compared to farm produced hay for the first land situation.

Farmers in the second land situation could profit from purchased hay at prices up to $14.27 per 1,000 pounds of TDN, and would grow native alfalfa and Bermuda hay when the market price went above $14.27. Millet and Sudan hay could also be harvested in this land situation, adding from $5.56 to $10.38 per animal unit to the total cost when compared to native, alfalfa and Bermuda hay. When hay is purchased (case 5) the cost is from $3.88 to $14.18 per animal unit cheaper than when all hay is grown on the farm.

The dairyman who does not purchase hay under the third land situation would incur a total cost $.70 per animal unit above the dairyman who purchases hay (case 18 vs. case 41). In the fourth land situation, hay is purchased at prices up to $14.27 per 1,000 pounds of TDN. At a market price above $14.27 per 1,000 pounds of TDN, it would be more profitable to grow Bermuda hay than to purchase hay.

The dairyman with no land suitable for alfalfa production would incur slightly higher total costs with respect to his roughage system. Dairymen with land suitable for alfalfa production have approximately equal opportunities for low cost roughage systems, since costs of analogous cases in each of the three land situations with alfalfa land differ by only $.18 to $1.76.

In summary, dairymen can expect to save from $6.00 to $16.00 per cow by applying the roughage producing practices recommended. Cost is minimized when a minimum amount of hay is harvested and all land is used for pasture. This is possible only when hay may be purchased at a low price. Growing hay is more profitable when the market price of hay exceeds $14.27 per 1,000 pounds of TDN, increasing the requirement for land for both hay and pasture.

Land Use

When hay is not purchased the requirement for land increases from .34 to 3.20 acres per animal unit compared to those cases where hay is purchased, or on the average the carrying capacity of the land is reduced by approximately half when no hay is purchased. If all hay is purchased, those dairymen with more class A_1 land generally require more land than those dairymen with less A_1 land. When all hay is grown on the farm there is very little difference in the land requirements between each land situation.

The three classes of land are utilized in each case according to summary Table XIV. Alfalfa pasture and hay utilize the class A_1 land, while Bermuda grass hay and rye grass pasture are the most profitable roughages to grow on the class A_2 land. Johnson grass pasture is the best source of roughage on the better class A_3 land while native pasture provides roughage on all class A_3 land. Those activities which appear occasionally are important when hay cannot be purchased at a very low price.

The dairyman who desires to maintain the maximum carrying capacity would do so by purchasing most of his hay at a low price, if possible, and establish alfalfa, rye grass and native pasture with Johnson grass. If the market price of hay is high or is expected to be high the carrying capacity of the land will be lower. If the supply of land were highly elastic it could be utilized according to the prevailing market prices for hay. For example, the dairyman with his class A_1 land in alfalfa, class A_2 land in rye grass and Bermuda and class A_3 land in Johnson grass and native grass, would harvest hay from a large portion of each class of land during years of high hay prices and would use these crops for pasture during years of low hay prices.

Milk Production

There is a wide variation in digestible protein content and palatability among different types of roughages. When high quality hay (alfalfa) cannot be purchased at a price below $14.27 per 1,000 pounds of TDN the roughage consumed by the cow will be low in protein and palatability for those cases where purchased hay is the only source of roughage during the winter. All programmed cases provide large quantities of high

TABLE XIV

ACTIVITIES APPEARING FREQUENTLY, OCCASIONALLY, AND NEVER IN PROGRAM RESULTS FOR THREE LAND CLASSES

Appeared in Program Results	Land Class A_1	A_2	A_3	Buying Activities
Frequently	Alfalfa pasture Alfalfa hay	Bermuda grass hay Rye grass pasture	Johnson grass pasture Native grass pasture	Hay at $11.56/1,000 TDN
Occasionally	Sudan hay	Rye-vetch pasture Vetch-oats-wheat pasture Bermuda pasture Millet hay	Native grass hay	Hay from $13.28 to $14.27/1,000 TDN
Never	Barley pasture Barley hay Lespedeza pasture Lespedeza hay Vetch pasture Wheat pasture	Cowpea pasture and hay Millet pasture Oat pasture and hay Rye pasture Rye grass hay Sudan pasture Bermuda-lespedeza pasture and hay Bermuda-hop clover hay Oats-rye pasture and hay Oats-vetch pasture and hay Rye-barley pasture and hay Rye-vetch hay Oats-barley-rye pasture and hay Vetch-oats-barley pasture and hay Vetch-oats-wheat hay	Johnson grass hay	Hay over $14.27/1,000 TDN Silage

protein and palatable roughage during the pasture season, primarily from alfalfa pasture. Over the period of a year enough digestible protein is available (600 to 900 pounds per cow) to permit a very low protein concentrate (8-10 per cent) to be fed, and still maintain milk production. This protein is not evenly distributed throughout the year for most cases so that the protein content of the concentrate must be adjusted to higher levels (16-20 per cent) during periods of low quality roughage feeding and to lower levels (12-16 per cent) during periods of high quality roughage feeding. For some cases, it is possible to arrange the roughage feeding program so that the low quality hay is fed when the cows are on high quality pasture and the high quality hay, if available, is fed when cows are on low quality or no pasture. This would distribute the protein available in the roughage, and reduce the necessity of adjusting the protein content of the concentrate ration. This is particularly true of cases 31, 35, 22 and 29 where both alfalfa and grass hay are grown on the farm.

Dairymen with no class A_1 land would not be able to obtain roughage of quality equivalent to those dairymen with class A_1 land available, at the same cost and level of land use. When the dairyman has no A_1 land he may improve the quality of his roughage by purchasing higher priced, higher quality hay and concentrates or by producing more costly higher quality hay on his class A_2 land such as small grain with vetch or Bermuda with lespedeza. He would therefore incur greater total costs than dairymen with some class A_1 land, to obtain equivalent protein from roughage.

Uncertainty

Although the theoretical framework of this study is static, certain subjective considerations of uncertainty have been made. The selection of input data was based on those conditions expected to prevail in the majority of cases over time. Some variation will occur with respect to yields and prices, and there are a number of ways to insure against such variations. Diversification is most applicable within the framework of this study. The dairyman may insure against uncertainty by not depending on the hay market entirely as a source of hay and/or establishing more than two or three types of pasture on the farm. By permitting some hay to be harvested on the farm, the dairyman protects himself against price variations in the hay market and by establishing several types of pasture he protects himself against yield uncertainty, providing all types of pasture are not affected in exactly the same way by the weather. Cases 18, 27, 29, 35 and 38 provide the best hedge against uncertainty through diversification.

CHAPTER VI

SUMMARY

The objectives of this study were to determine the least cost sources of roughage for dairy animals on Grady and Lincoln County farms, given the existing factors of production.

Existing factors of production were determined through a survey of selected dairy farms in Grady and Lincoln counties. Certain data was obtained from secondary sources as a supplement to the survey data. The mathematical tool used to derive the least cost combination was linear programming. The significance of the programmed results were analyzed with respect to each of the objectives. The implications of certain assumptions of linear programming were discussed in terms of their effect upon, and adjustment in, the programmed results.

Roughage systems were derived which, if put into actual practice by the dairyman in the area of the study, would: (1) reduce roughage costs by at least $10 per animal unit for most dairy farmers, (2) nearly double carrying capacity of the land when hay is purchased, and (3) provide almost half again as much carrying capacity when hay is not purchased.

These low cost roughage systems are accomplished by: (1) utilizing pastures with high seasonal yields, to the maximum, when that pasture is available, (2) feeding hay during the off-pasture season, (3) buying the hay when cost per 1,000 pounds of TDN at the farm gate is less than $14.27, and (4) growing and harvesting the hay on the farm if the market price goes above $14.27.

The implication of (1) is that the dairyman should not attempt to get all year pastures, but should establish the type of pasture which provides the highest yield per dollar, regardless of the seasonal distribution of that yield. On the poorer classes of land (A_3), native grass pasture backed up with Johnson grass where the land will support it, is the most profitable. On the class A_2 land rye grass, Bermuda pasture and rye-vetch pasture are the most profitable, and on the class A_1 land alfalfa pasture is the most profitable.

The implication of (2) is that hay is a cheaper source of roughage in the winter than pasture or silage. Land that would otherwise be committed to winter pasture is used more intensively for summer pasture and/or hay production.

The implication of (3) and (4) is that the cost of farm harvested hay is less than the maximum price of purchased hay as indicated. Hay would only be grown and harvested on the farm when the land is available and hay prices are high. Farmers would be willing to pay more than $14.27 per 1,000 pounds of TDN for hay if no land was available for growing and harvesting it. When hay is to be grown and harvested on the farm the most profitable type of hay is Bermuda grass on the class A_2 land, native grass on the class A_3 land and alfalfa on the class A_1 land. Occasionally millet hay on class A_2 and Sudan hay on class A_1 land are the best uses of that land.

Dairymen with relatively less class A_1 land and who purchase all their hay would have a slight cost and carrying capacity advantage over those dairymen with relatively more class A_1 land. When all hay is grown and harvested on the farm there is no significant difference in roughage costs among the four land situations studied but the quality of roughage is better when there is relatively more type A_1 land.

Dairymen who reorganize their roughage producing resources in the directions indicated in this study can expect reduced costs with respect to roughage production while maintaining milk output, thus yielding a greater net income for the farm family.

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A P P E N D I X

APPENDIX TABLE I

PASTURE USE AND INTENSITY INDEX,[a] 23 SAMPLE FARMS, LINCOLN COUNTY (1960)

Farm Number	Animal Unit Days Per Acre on: Native	Bermuda	Sudan	Wheat	Oats-Vetch	Native Bermuda	Other[b]	ΣAUD /Acre	Total AU	Intensity Index
1	274	-	-	-	-	-	-	274	38	7.2
2	26	-	-	83	-	-	-	109	57	1.9
3	32	-	-	-	23	-	-	55	51	1.1
4	77	-	-	-	-	-	-	77	44	1.7
5	38	-	-	586	-	-	-	624	120	5.2
6	-	22	72	-	-	-	248	342	54	6.4
7	45	-	-	-	-	-	-	45	116	0.4
8	105	-	-	-	-	-	-	105	76	1.4
9	33	-	-	-	-	-	-	33	72	0.5
10	51	-	-	-	-	25	-	76	46	1.6
11	34	-	280	-	-	-	664	978	76	12.9
12	38	-	237	-	101	-	-	376	109	3.5
13	-	46	136	-	-	-	234	416	94	4.4
14	43	115	-	-	-	53	84	295	97	3.0
15	-	41	-	-	-	-	36	77	53	1.5
16	32	-	-	-	-	16	125	173	67	2.6
17	127	-	-	-	-	-	85	212	71	2.9
18	99	-	-	-	-	-	36	135	52	2.6
19	34	-	-	-	-	-	-	34	46	0.7
20	19	-	-	-	48	-	172	239	41	5.8
21	62	36	-	-	-	-	100	198	88	2.2
22	30	-	-	-	-	-	335	365	68	5.4
23	27	-	-	-	64	-	34	125	69	1.8
Average	61.3	52	182.5	335	59	31.3	179.4	233.2	69.78	3.3

[a]All figures are rounded to the nearest whole number. The intensity index for each farm is derived by dividing ΣAUD/acre by total AU.

[b]Other includes: Oats, alfalfa, lespedeza-Bermuda, rye-vetch, native-rye, wheat-vetch-rye, Bermuda-Johnson grass, Sudan-rye, Sudan-Johnson grass, oats-wheat-vetch, vetch, wheat-Sudan, rye-onions, native-Bermuda-lespedeza, clover-Bermuda-lespedeza, wheat-Johnson grass, and sorgo.

APPENDIX TABLE II

PASTURE USE AND INTENSITY INDEX,[a] 25 SAMPLE FARMS, GRADY COUNTY (1960)

Farm Number	Animal Unit Days Per Acre on: Native	Rye Vetch	Sudan	Wheat	Oats-Wheat	Oats	Alfalfa	Other[b]	ΣAUD /Acre	Total AU	Intensity Index
1	91	-	-	-	-	-	-	-	91	54	1.7
2	22	-	-	-	104	-	-	-	126	108	1.2
3	12	327	-	-	-	-	-	-	339	44	7.7
4	57	99	-	-	-	-	-	-	156	54	2.9
5	-	76	693	-	-	-	-	-	769	34	22.5
6	60	-	-	27	-	32	-	-	119	71	1.7
7	211	-	-	37	-	-	-	-	248	67	3.7
8	80	245	140	-	-	-	-	-	465	39	12.1
9	-	275	153	-	-	267	-	-	695	64	10.9
10	55	303	-	-	-	33	124	45	560	62	9.0
11	193	-	-	147	-	-	-	-	340	58	5.9
12	73	-	-	40	-	83	-	-	196	134	1.5
13	69	-	292	-	-	-	-	72	433	58	7.4
14	44	-	-	20	-	8	-	-	72	55	1.3
15	-	-	258	-	203	-	203	-	664	55	12.0
16	350	-	208	320	-	8	-	17	903	78	11.5
17	115	-	242	315	-	-	-	569	1,241	204	6.1
18	-	212	-	-	-	-	-	192	404	61	6.6
19	25	69	21	65	-	77	-	57	314	41	7.6
20	39	20	60	121	-	150	-	-	390	51	7.7
21	41	-	40	26	-	-	-	-	107	35	3.0
22	41	39	-	88	-	-	13	152	333	92	3.6
23	22	150	395	102	-	106	-	-	775	62	12.5
24	-	-	-	-	-	135	38	-	173	41	2.1
25	24	-	24	343	-	-	-	29	420	102	4.1
Average	81.2	165	210.5	117.9	153.5	89.9	94.5	141.6	413.3	68.96	6.7

[a] All figures are rounded to the nearest whole number. The intensity index for each farm is derived by dividing ΣAUD/acre by total AU.

[b] Other includes: Barley, sorghum alma, oats-vetch, native-Bermuda, midland-Bermuda, and barley-oats.

APPENDIX TABLE III

INTENSITY INDEX, 48 GRADY AND LINCOLN COUNTY DAIRY FARMS GROUPED INTO SIX PASTURE SYSTEMS (1960)

Pasture Systems											
I		II		III		IV		V		VI	
Farm[a]	Index[b]	Farm	Index	Farm	Index	Farm	Index	Farm	Index	Farm	Index
L-11	12.88	L-12	3.47	L-10	1.62	L- 6	6.37	L- 3	1.07	L- 1	7.20
L-22	5.38	L-14	3.04	L-16	2.57	L-13	4.40	L- 5	5.21	L- 2	1.90
G-10	9.05	L-17	2.99	L-18	2.57	L-15	1.46	L-23	1.80	L- 4	1.75
G-23	3.61	L-20	5.78	G-13	7.43	G- 5	22.57	G- 2	1.17	L- 7	0.39
		L-21	2.25			G- 9	10.93	G- 3	7.69	L- 8	1.39
		G- 8	12.09			G-15	12.03	G- 4	2.87	L- 9	0.45
		G-16	11.52			G-25	2.09	G- 6	1.69	L-19	0.73
		G-17	6.09					G- 7	3.69	G- 1	1.70
		G-18	6.65					G-11	5.86		
		G-19	7.62					G-12	1.46		
		G-20	7.69					G-14	1.29		
		G-21	3.05								
		G-24	12.49								
		G-26	4.11								
Total	30.92		88.84		14.19		59.85		33.80		15.51
Average	7.73		6.35		3.55		8.55		3.07		1.94

[a]The letter prefix to farm numbers refers to the county: L = Lincoln and G = Grady.

[b]See Appendix Tables I and II.

APPENDIX TABLE IV

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING, FOUR SAMPLE FARMS IN PASTURE SYSTEM I

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 1,835 Acres	215	215	256	256	280	280	289	253	253	200	200	200	
B	AUM/Acre	.1316	.1316	.1566	.1566	.1712	.1712	.1764	.1544	.1544	.1224	.1224	.1224	
C	Lbs. Pasture /Acre	239	239	285	285	311	311	321	281	281	222	222	222	3,219
D	Lbs. TDN /Acre	39.5	39.5	47.0	47.0	51.4	51.4	52.9	46.3	46.3	36.7	36.7	36.7	531.4
E	TDN/AU Consumed	173	173	206	206	226	226	233	204	204	162	162	162	2,327
F	Hay Fed TDN/AU	160	160	136	138	132	142	137	159	148	176	172	169	1,829
G	Silage Fed TDN/AU	114	114	96	99	94	101	98	113	105	125	123	120	1,302
H	Hay Plus Silage Fed	274	274	232	237	226	243	237	272	253	301	295	289	3,133
I	Total, Hay Silage, and Pasture	447	447	438	443	452	469	470	476	457	463	457	441	5,460

[1]Row A - Total number of animal units on total number of acres of pasture for the particular month.
Row B - Animal unit months per acre, derived by dividing figures in Row A by total number of acres.
Row C - Lbs. pasture/acre, derived by following: $\frac{\text{8 lbs. TDN cow will consume}}{\text{Average past. \% TDN}}$ x days/mo. x Row B = Row C.
Row D - Lbs. TDN/acre, derived by multiplying Row C by % TDN for pasture.
Row E - TDN/animal unit consumed, derived by multiplying Row D times acre/AU.
Row F, G and H - Lbs. of TDN fed by interpolating between total roughage fed, roughage obtained from pasture and total roughage required by the AU/mo.
Row I - Total TDN obtained by AU/mo. from all sources.

APPENDIX TABLE V

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING, FOURTEEN SAMPLE FARMS IN PASTURE SYSTEM II

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 4,409 Acres	773	773	909	799	767	860	924	930	886	846	837	885	
B	AUM/Acre	.1753	.1753	.2061	.1812	.1739	.1952	.2096	.2110	.2010	.1920	.1898	.2007	
C	Lbs. Pasture /Acre	306	306	359	316	303	340	366	368	351	335	331	350	4,031
D	Lbs. TDN /Acre	52.6	52.6	61.8	54.4	52.1	58.6	62.9	63.3	60.3	57.6	56.9	60.2	693.3
E	TDN/AU Consumed	172	172	202	177	170	193	206	206	196	196	190	206	2,286
F	Hay Fed TDN/AU	187	187	169	187	198	196	188	188	183	179	179	166	2,207
G	Silage Fed TDN/AU	60	60	54	60	64	63	60	60	59	58	58	54	710
H	Hay Plus Silage Fed	247	247	223	247	262	259	248	248	242	237	237	220	2,917
I	Pasture, Hay and Silage	419	419	425	424	432	452	454	454	438	433	427	426	5,203

[1]See Appendix Table IV for appropriate footnote.

APPENDIX TABLE VI

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING, FOUR SAMPLE FARMS IN PASTURE SYSTEM III

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 1,114 Acres	189	189	211	225	203	225	225	225	203	203	203	203	
B	AUM/Acre	.1693	.1693	.1893	.2019	.1819	.2019	.2019	.2019	.1819	.1819	.1819	.1819	
C	Lbs. Pasture /Acre	277	277	310	331	298	331	331	331	298	298	298	298	3,678
D	Lbs. TDN /Acre	51.7	51.7	57.8	61.7	53.9	61.7	61.7	61.7	53.9	53.9	53.9	53.9	677.5
E	TDN/AU Consumed	206	206	230	246	214	246	246	246	214	214	214	214	2,696
F	Hay Fed TDN/AU	111	111	102	98	115	109	109	109	115	113	110	108	1,380
G	Silage Fed TDN/AU	117	117	107	103	121	115	115	115	121	119	116	114	1,380
H	Hay Plus Silage Fed	228	228	209	201	236	224	224	224	236	232	226	222	2,690
I	Pasture, Hay and Silage	434	434	439	447	450	470	470	470	450	446	440	436	5,386

[1] See Appendix Table IV for appropriate footnote.

APPENDIX TABLE VII

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING, SEVEN SAMPLE FARMS IN PASTURE SYSTEM IV

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 1,049 Acres	214	214	327	339	344	344	344	344	239	232	160	160	
B	AUM/Acre	.2036	.2036	.3116	.3230	.3277	.3277	.3277	.3277	.2277	.2210	.1521	.1521	
C	Lbs. Pasture /Acre	382	382	584	606	614	614	614	614	427	414	285	285	5,821
D	Lbs. TDN /Acre	61.1	61.1	93.5	96.9	98.3	98.3	98.3	98.3	68.3	66.3	45.6	45.6	931.6
E	TDN/AU Consumed	127	127	194	202	204	204	204	204	142	138	95	95	1,936
F	Hay Fed TDN/AU	263	263	214	212	220	233	233	233	265	264	291	286	2,977
G	Silage Fed TDN/AU	71	71	58	57	59	63	63	63	71	71	78	77	802
H	Hay Plus Silage Fed	334	334	272	269	279	296	296	296	336	335	369	363	3,779
I	Pasture, Hay and Silage	461	461	466	471	483	500	500	500	478	473	464	458	5,715

[1]See Appendix Table IV for appropriate footnote.

APPENDIX TABLE VIII

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING
ELEVEN SAMPLE FARMS IN PASTURE SYSTEM V

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 4,538 Acres	557	557	626	663	657	588	588	588	588	551	500	500	
B	AUM/Acre	.1227	.1227	.1379	.1460	.1447	.1295	.1295	.1295	.1295	.1213	.1101	.1101	
C	Lbs. Pasture /Acre	217	217	244	258	256	229	229	229	229	215	195	195	2,713
D	Lbs. TDN /Acre	36.8	36.8	41.4	43.8	43.4	38.9	38.9	38.9	38.9	36.4	33.0	33.0	460.2
E	TDN/AU Consumed	161	161	161	191	190	170	170	170	170	159	144	144	1,991
F	Hay Fed TDN/AU	256	256	256	238	248	278	278	278	263	267	274	270	3,162
G	Silage Fed TDN/AU	41	41	41	38	39	44	44	44	42	42	43	43	502
H	Hay Plus Silage Fed	297	297	297	276	287	322	322	322	305	309	317	313	3,664
I	Pasture Hay and Silage	458	458	458	467	477	492	492	492	475	468	461	457	5,655

[1]See Appendix Table IV for appropriate footnote.

APPENDIX TABLE IX

DISTRIBUTION OF PASTURE CONSUMPTION, HAY AND SILAGE FEEDING, EIGHT SAMPLE FARMS IN PASTURE SYSTEM VI

Row[1]	Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A	Total AU on 2,863 Acres	326	326	326	442	492	492	492	492	442	442	326	326	
B	AUM/Acre	.1140	.1140	.1140	.1543	.1718	.1718	.1718	.1718	.1543	.1543	.1140	.1140	
C	Lbs. Pasture /Acre	175	175	175	236	263	263	263	263	236	236	175	175	2,635
D	Lbs. TDN /Acre	34.2	34.2	34.2	46.3	51.5	51.5	51.5	51.5	46.3	46.3	34.2	34.2	515.9
E	TDN/AU Consumed	156	156	156	211	235	235	235	235	211	211	156	156	2,353
F	Hay Fed TDN/AU	217	217	217	185	177	189	189	189	193	189	221	217	2,400
G	Silage Fed TDN/AU	78	78	78	67	64	68	68	68	70	68	80	78	865
H	Hay Plus Silage Fed	295	295	295	252	241	257	257	257	263	257	301	295	3,265
I	Pasture, Hay and Silage	451	451	451	463	476	492	492	492	474	468	457	451	5,618

[1]See Appendix Table IV for appropriate footnote.

APPENDIX TABLE X

PROGRAMMED ACTIVITIES AND IDENTIFYING NUMBERS

Activity Number	Type of Activity
1	Alfalfa pasture
2	Bermuda grass pasture
3	Johnson grass pasture
4	Native grass pasture
5	Rye-vetch pasture
6	Growing alfalfa hay
7-18	Feeding alfalfa hay
19	Growing Bermuda hay
20-31	Feeding Bermuda hay
32	Barley pasture
33	Cowpea pasture
34	Lespedeza pasture
35	Millet pasture
36	Oat pasture
37	Rye pasture
38	Sudan pasture
39	Lespedeza-Bermuda pasture
40	Vetch pasture
41	Wheat pasture
42	Rye grass pasture
43	Vetch-oats-wheat pasture
44	Vetch-oats pasture
45	Vetch-oats-barley pasture
46	Oats-rye pasture
47	Barley-rye pasture
48	Oats-barley-rye pasture
49	Growing native hay
50-61	Feed native grass hay
115	Buy hay

APPENDIX TABLE XI

PROGRAMMED RESULTS, FIRST LAND SITUATION

Case Number	Activity Number	Cost /Acre	Total Acres	Shadow Prices Upper Bound	Entering Activity	Lower Bound	Entering Activity
1	5	$19.29	4.17	$20.33	30	$17.77	56
	3	6.52	90.30	9.87	2	3.97	56
	42	9.00	38.54	11.11	56	.95	32
	1	14.66	47.62	18.05	32	9.82	56
	115	22.00	173.69	22.86	30	20.17	2
2	3	6.52	90.11	11.82	4	5.68	56
	19	50.79	3.84	50.96	5	50.79	59
	42	9.00	38.78	9.70	56	9.00	30
	1	14.66	47.52	18.01	32	13.06	56
	115	23.00	168.71	23.16	25	23.00	30
13	3	6.52	116.18	8.05	4	3.52	6
	19	50.79	66.02	53.60	5	43.75	4
	1	14.66	73.61	16.61	6	8.34	4
	49	26.19	23.39	27.25	115	23.76	42
21	3	6.52	84.76	9.71	5	6.50	6
	1	14.66	81.23	14.69	6	7.57	5
	19	50.79	72.85	50.88	6	22.90	28
	4	5.87	69.26	5.89	6	4.15	5
31	3	6.52	132.52	6.53	4	5.06	5
	1	14.66	48.46	22.19	5	14.64	4
	19	50.79	62.68	54.99	5	50.74	4
	6	51.02	21.43	51.05	4	45.42	5

(Continued)

APPENDIX TABLE XI (Continued)

Case Number	Activity Number	Cost /Acre	Total Acres	Shadow Prices: Upper Bound	Entering Activity	Lower Bound	Entering Activity
38	5	$19.29	8.41	$19.29	24	$ 8.89	18
	3	9.72	75.38	10.01	2	9.71	24
	1	14.66	85.45	14.67	24	13.08	2
	4	5.87	86.64	5.88	24	5.66	2
35	1	14.66	17.78	16.31	2	10.34	4
	3	6.52	152.45	9.46	4	101.07	114
	6	51.02	62.61	57.75	4	49.21	2
	5	19.29	45.79	22.24	11	16.06	2
	19[1]	32.79	26.31	33.97	2	29.69	24

[1]Activity 19 is millet hay in this case.

APPENDIX TABLE XII

PROGRAMMED RESULTS, SECOND LAND SITUATION

				Shadow Prices			
Case Number	Activity Number	Cost /Acre	Total Acres	Upper Bound	Entering Activity	Lower Bound	Entering Activity
5	42	$ 9.00	37.47	$11.25	5	$ 2.97	115
	3	6.52	112.20	9.67	4	4.30	5
	1	14.66	15.74	18.56	32	1.15	5
	115	22.00	193.38	23.35	25	8.50	58
10	3	6.52	146.22	8.73	4	3.69	16
	1	14.66	27.35	16.50	17	7.35	4
	19	50.79	65.14	51.71	115	41.54	4
	49	26.19	48.80	26.48	115	23.63	42
22	3	6.52	142.66	7.19	1	4.61	115
	4	5.87	55.82	6.57	17	5.48	1
	19	50.79	66.29	54.33	115	47.94	1
	6	51.02	27.84	52.52	1	23.32	5
28	3	6.52	79.70	10.57	2	5.52	17
	1	14.66	34.01	16.18	7	9.24	5
	19	50.79	80.99	53.17	115	18.43	28
	4	5.87	162.78	6.32	115	3.97	5
25	3	6.52	150.30	71.07	4	5.59	17
	1	14.66	21.08	15.26	7	11.49	4
	19	50.79	50.20	57.00	5	49.46	4
	115	60.00	38.71	60.91	7	50.11	5

(Continued)

APPENDIX TABLE XII (Continued)

Case Number	Activity Number	Cost /Acre	Total Acres	Shadow Prices Upper Bound	Entering Activity	Lower Bound	Entering Activity
29	4	$ 5.87	210.36	$ 7.89	11	$ 5.87	13
	3	6.52	83.62	10.26	1	6.52	13
	6	51.02	41.23	60.04	1	3.77	2
	19[1]	32.79	69.48	36.15	25	32.79	13
27	3	6.52	61.69	8.05	1	5.08	7
	5	19.29	22.08	20.03	7	17.46	21
	6[2]	36.47	46.21	39.04	1	.93	21
	4	5.87	267.73	6.46	7	4.85	1
	19[1]	32.79	87.94	34.62	21	32.05	7

[1]Activity number 19 is millet hay in this case.

[2]Activity number 6 is Sudan hay in this case.

APPENDIX TABLE XIII

PROGRAMMED RESULTS, THIRD AND FOURTH LAND SITUATIONS

				Shadow Prices			
Case Number	Activity Number	Cost /Acre	Total Acres	Upper Bound	Entering Activity	Lower Bound	Entering Activity
18	2	$ 9.04	12.05	$ 9.20	55	$ 9.04	22
	3	6.52	77.78	7.02	54	6.52	22
	19	50.79	9.38	51.00	54	50.79	22
	5	19.29	35.25	19.81	29	19.29	22
	1	14.66	77.78	15.15	54	14.66	22
	42	9.00	21.09	12.87	54	7.43	25
	115	22.00	115.05	22.04	55	22.00	21
41	42	9.00	16.09	9.87	5	5.50	61
	1	14.66	88.59	18.26	32	13.37	5
	3	6.52	88.59	8.28	4	5.23	5
	19	50.79	72.49	51.53	5	20.44	28
9	42	9.00	14.60	13.35	2	2.39	115
	43	20.66	34.76	45.99	115	9.19	1
	3	6.52	147.80	12.48	115	1.85	5
	115	22.00	190.08	24.70	22	11.61	58
37	3	6.52	142.66	7.19	1	4.61	115
	4	5.87	55.82	6.57	17	5.48	1
	19	50.79	66.29	54.33	115	47.94	1
	6	51.02	27.84	52.52	1	23.32	5

APPENDIX TABLE XIV

PROGRAMMED RESULTS, DISTRIBUTION OF HAY FEEDING FOR EACH CASE, TOTAL POUNDS OF HAY IN THOUSANDS

Case No.	January	February	March	April	May	June	July	August	September	October	November	December
1	93.1	92.9	82.2	49.4	36.2	23.6	0	19.3	0	4.5	83.6	92.8
2	93.4	93.4	83.5	52.1	44.1	25.4	0	19.3	0	5.9	84.6	93.4
13	113.0	113.0	95.6	41.8	19.6	23.8	23.8	22.8	0	9.9	98.9	77.9
21	113.0	113.0	96.3	43.9	10.2	11.9	15.6	18.9	0	6.9	98.5	113.0
31	113.0	113.0	98.5	49.9	28.3	32.4	32.4	29.3	0	14.5	93.3	96.6
38	112.2	111.7	93.6	35.5	0	3.8	12.4	17.3	0	4.9	95.6	111.4
35	92.7	90.4	75.5	22.2	0	16.8	35.2	31.6	0	13.1	79.7	87.1
5	93.2	93.2	86.4	60.2	47.8	34.4	9.9	26.3	0	10.0	88.5	93.4
10	113.0	113.0	100.9	56.7	35.5	39.7	39.7	34.7	0	18.5	90.7	93.4
22	113.0	113.0	105.2	69.2	39.4	40.5	38.1	34.5	0	19.1	109.4	96.6
28	113.0	113.0	103.6	65.2	17.3	15.5	24.3	28.6	0	13.6	105.8	113.0
25	113.0	113.0	100.8	58.7	37.7	41.8	41.8	37.3	0	19.6	106.0	113.0
29	93.5	90.6	85.3	48.5	0	5.3	25.9	30.9	0	13.7	87.7	89.8
27	92.5	97.1	86.7	59.1	1.7	0	23.6	30.6	0	12.9	87.7	90.9
18	101.7	88.8	71.6	20.7	0	0	0	18.1	0	3.5	73.1	87.9
41	113.0	113.0	95.7	42.7	22.5	18.0	5.1	16.4	0	3.5	97.6	113.0
9	92.0	91.2	82.6	47.9	31.3	32.9	29.8	32.7	0	15.3	86.0	90.8
37	113.0	113.0	105.2	69.2	39.4	40.5	38.1	34.5	0	19.1	109.4	96.6

APPENDIX TABLE XV

ESTIMATED TOTAL COST, 48 SAMPLE FARMS GROUPED INTO SIX PASTURE SYSTEMS, GRADY AND LINCOLN COUNTIES (1960)

System Number	Farm Number	ΣTC Pasture	ΣTC Hay Harvested	ΣTC Hay Purchased	ΣTC Silage Purchased	ΣTC All Roughage	AU	TC /AU	Corrected to 6,000 Pounds
	L-11	$5,766	-	$1,200	-	-	76	-	-
	L-22	1,063	$ 732	-	-	-	68	-	-
	G-10	2,728	2,469	-	-	-	62	-	-
	G-23	4,878	1,708	1,000	$ 300	-	92	-	-
I		14,435	4,909	2,200	300	$21,844	298	$73.30	$80.52
	L-12	3,724	-	700	-	-	109	-	-
	L-14	978	1,423	324	-	-	97	-	-
	L-17	1,027	-	300	-	-	71	-	-
	L-20	4,452	5,059	750	-	-	41	-	-
	L-21	1,246	1,304	375	-	-	88	-	-
	G- 8	881	-	200	-	-	38	-	-
	G-16	1,478	2,622	-	-	-	78	-	-
	G-17	4,082	4,881	1,000	-	-	204	-	-
	G-18	2,236	1,717	-	-	-	60	-	-
	G-19	2,166	-	792	-	-	41	-	-
	G-20	2,566	920	1,000	250	-	51	-	-
	G-21	3,066	732	-	-	-	35	-	-
	G-24	2,663	976	2,054	-	-	62	-	-
	G-26	4,361	2,440	-	-	-	102	-	-
II		34,926	22,074	7,495	250	64,745	1,077	60.12	69.34
	L-10	1,138	2,163	-	-	-	46	-	-
	L-16	1,932	1,151	350	-	-	67	-	-
	L-18	1,289	-	400	-	-	52	-	-
	G-13	1,692	1,304	380	-	-	58	-	-
III		6,051	4,618	1,130	-	11,799	223	72.59	80.87

(Continued)

APPENDIX TABLE XV (Continued)

System Number	Farm Number	ΣTC Pasture	ΣTC Hay Harvested	ΣTC Hay Purchased	ΣTC Silage Purchased	ΣTC All Roughage	AU	TC /AU	Corrected to 6,000 Pounds
	L- 6	724	4,626	-	-	-	54	-	-
	L-13	2,452	2,684	-	-	-	94	-	-
	L-15	167	-	5,440	-	-	53	-	-
	G- 5	1,348	493	360	-	-	34	-	-
	G- 9	1,481	-	640	-	-	63	-	-
	G-15	935	781	-	2,750	-	55	-	-
	G-25	1,376	1,464	1,300	-	-	41	-	-
IV		8,474	10,048	7,740	2,750	29,012	394	73.63	77.32
	L- 3	3,712	2,907	-	-	-	51	-	-
	L- 5	2,894	6,578	119	-	-	120	-	-
	L-23	2,950	361	-	-	-	69	-	-
	G- 2	5,873	-	7,280	-	-	107	-	-
	G- 3	4,051	-	500	-	-	44	-	-
	G- 4	2,377	-	-	-	-	54	-	-
	G- 6	2,115	976	-	-	-	70	-	-
	G- 7	1,711	1,952	32	800	-	67	-	-
	G-11	706	3,449	1,000	-	-	58	-	-
	G-12	4,966	-	-	-	-	134	-	-
	G-14	9,410	1,074	-	-	-	55	-	-
V		40,765	17,297	8,931	800	67,793	829	81.78	86.77
	L- 1	269	-	380	-	-	38	-	-
	L- 2	4,938	-	850	-	-	57	-	-
	L- 4	909	657	570	-	-	44	-	-
	L- 7	2,931	-	-	-	-	115	-	-
	L- 8	1,398	2,196	-	-	-	66	-	-
	L- 9	3,312	-	3,480	-	-	72	-	-
	L-19	2,396	2,640	75	-	-	46	-	-
	G- 1	1,156	-	-	-	-	53	-	-
VI		17,336	5,493	5,355	-	28,184	491	57.40	63.92

APPENDIX TABLE XVI

DISTRIBUTION OF PASTURE YIELDS FOR TYPES OF PASTURE APPEARING IN PROGRAM RESULTS, BASED ON PROGRAMMING INPUT DATA, POUNDS OF TDN PER MONTH PER ACRE

Type Pasture	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alfalfa	0	0	64	221	271	271	271	274	200	237	60	0
Barley	242	301	382	44	264	0	0	0	0	0	0	125
Bermuda	0	0	57	125	125	85	125	51	0	0	0	0
Johnson Grass	0	0	24	128	189	189	189	208	307	242	14	0
Millet	0	0	0	0	0	103	255	133	151	162	7	0
Native	0	0	0	21	115	130	107	91	117	102	1	0
Oats	151	188	238	275	165	0	0	0	0	0	22	57
Rye Grass	0	0	0	0	0	233	574	299	341	366	17	0
Rye-Vetch	43	69	129	318	365	219	17	0	0	43	124	82
Vetch-Oats-Wheat	20	33	62	153	176	105	8	0	0	21	60	39
Wheat	92	131	167	192	115	0	0	0	0	0	15	54

APPENDIX TABLE XVII

DISTRIBUTION OF PASTURE YIELDS, INPUT DATA APPLIED TO SAMPLE FARMS ON FOUR LAND SITUATIONS, POUNDS OF TDN PER MONTH PER ANIMAL UNIT

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Situation 1, Figure 28	31	44	64	155	363	381	354	287	371	328	24	23
Situation 2, Figure 29	114	151	208	348	539	460	390	319	381	349	47	60
Situation 3, Figure 30	37	52	71	159	388	406	369	286	360	328	28	25
Situation 4, Figure 31	85	118	162	337	704	661	524	424	540	490	61	63

VITA

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