1969

An analysis of the feeder cattle enterprise on Iowa farms with the use of linear programming techniques

James Roger Ahrenholz
Iowa State University

AN ANALYSIS OF THE FEEDER CATTLE ENTERPRISE ON IOWA FARMS WITH THE USE OF LINEAR PROGRAMMING TECHNIQUES

by

James Roger Ahrenholz

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Major Subject: Agricultural Economics

Iowa State University
Of Science and Technology
Ames, Iowa

1969

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INTRODUCTION

Cattle feeding has long been an important enterprise on many Iowa farms. Iowa ranks as the leading cattle feeding state in the nation. Table 1 indicates that over 30% of all Iowa farms fed cattle between 1960 and 1965.

Cattle feeding is defined in this study to mean the finishing of cattle to slaughter weight. The farm operator that includes the finishing of cattle as part of the farm activities will be referred to as a farmer feeder.

The farm distribution of cattle on feed is shown in Tables 2 and 3. Table 2 shows the number of farms feeding cattle by size groups. Table 3 shows the relative importance of each size group in the total feeder cattle industry in Iowa. Both tables show the changes that have taken place over the period between 1960 and 1965. By comparing Tables 1, 2 and 3 it can be observed that:

(1) Out of the one third of all farmers that fed cattle, a third of these marketed less than 25 head per year and over 70% marketed less than 100 head.

(2) Those cattle feeders that marketed less than 100 head accounted for less than 40% of the total cattle marketed.

Table 1. Iowa farms reporting grain fed cattle marketed as number and percent of total farms[a]

Year	Number of Iowa farms	Farms reporting grain fed cattle marketed: Number farms	Percent total farms
1960	180,595	55,954	31
1961	177,172	54,651	31
1962	173,615	51,446	30
1963	170,030	51,788	30
1964	165,890	50,640	31
1965	153,669	48,991	32

[a] Source: Iowa Crop and Livestock Reporting Service (10).

Table 2. Iowa farms reporting grain fed cattle marketed by size groups - reported by year[a]

Year	Farms reporting number	Farms reporting grain fed cattle marketed by size group - as percent of total						
		< 25 %	25-49 %	50-99 %	100-299 %	300-499 %	≥500 %	Total %
1960	55,954	41.6	25.1	19.6	12.0	1.2	0.5	100.0
1961	54,651	41.8	24.6	19.2	12.6	1.3	0.5	100.0
1962	51,446	40.9	23.8	19.2	13.8	1.6	0.7	100.0
1963	51,788	38.8	23.5	19.9	15.2	1.8	0.8	100.0
1964	50,640	39.0	23.0	19.6	15.4	2.0	1.0	100.0
1965	48,991	37.0	23.4	19.6	16.5	2.3	1.2	100.0

[a] Source: Ibid.

Table 3. Number of Iowa grain fed cattle marketed by size groups - reported by year[a]

Year	Total grain fed cattle marketed	Grain fed cattle marketed by size group - as percent of total						
		<25 %	25-49 %	50-99 %	100-299 %	300-499 %	≥500 %	Total %
1960	3,013,937	10.1	16.3	24.7	33.7	7.6	7.6	100.0
1961	3,033,578	9.8	15.5	23.5	34.5	8.2	8.5	100.0
1962	3,055,304	8.8	14.0	22.1	35.5	9.8	9.8	100.0
1963	3,289,960	7.9	13.0	21.5	36.7	10.2	10.7	100.0
1964	3,348,372	7.6	12.2	20.3	36.1	11.1	12.7	100.0
1965	3,520,636	6.8	11.4	18.7	36.0	11.8	15.3	100.0

[a]Source: Ibid.

(3) Less than 2% of the cattle feeders fed more than 500 head of cattle but still accounted for more than 15% of the total marketings.

(4) For the six-year period shown, the number of cattle feeders marketing less than 25 head declined by nearly 1% per year while those marketing 100 to 500 head increased by nearly 1% per year. The percentage of the total cattle marketed by size group changed in about the same manner.

The larger feedlots with over 500 head have been increasing by about .1% per year but the percentage of the total cattle marketed they account for has been increasing by over 1% per year.

This study will concentrate on the 100 to 500 head size feedlots that market 50% of the total grain fed cattle in Iowa. Fewer cattle than this would not represent a major enterprise consideration on commercial size farms and more than this number of cattle would probably represent commercial feedlots where most of the feed is purchased and not farm raised. This study focuses upon the integration of the feeder cattle activity with other crop and livestock activities of the farm.

Tables 4 and 5 show the distribution of cattle feeding during 1965 in the nine crop reporting districts of Iowa by number of cattle fed and number of farms, respectively. The nine districts can be seen in Figure 1. Of the nine districts in Iowa, the northwest district has both the largest number of farms reporting grain fed cattle marketed and the largest number of grain fed cattle marketed. In this area, 75% of the farms marketed less than 100 head but accounted for less than 30% of the total cattle marketed in 1965. The 24% of the farms that reported marketing 100 to 500 head accounted for 50% of the total cattle marketed from that area. Only slight derivations from this same marketing distribution pattern existed in the other districts. For the above reasons, plus the availability of data, the northwest district was selected as the location of the farm situation used in this study.

Table 4. Number of Iowa grain fed cattle marketed by size groups - reported by district for 1965[a]

District	Total grain fed cattle marketed	Grain fed cattle marketed by size group - as percent of total 25 %	25-49 %	50-99 %	100-299 %	300-499 %	500 %	Total %
Northwest	785,339	4.6	8.7	16.3	36.9	13.0	20.5	100.0
North Central	308,101	9.9	13.8	22.4	34.5	9.1	10.3	100.0
Northeast	154,852	9.9	14.5	19.4	34.8	10.9	10.5	100.0
West Central	676,109	5.7	9.9	17.0	34.8	13.0	19.6	100.0
Central	478,063	7.2	12.8	20.8	38.0	11.8	9.4	100.0
East Central	457,946	6.7	11.9	21.7	38.5	10.1	11.1	100.0
Southwest	399,415	6.0	10.5	15.2	33.7	13.3	21.3	100.0
South Central	90,199	13.3	19.8	20.6	30.6	10.5	5.2	100.0
Southeast	170,612	11.1	14.9	20.9	35.7	9.6	7.8	100.0
State	3,520,636	6.8	11.4	18.7	36.0	11.8	15.3	100.0

[a]Source: Ibid.

Table 5. Iowa farms reporting grain fed cattle marketed by size groups - reported by district for 1965[a]

District	Farms reporting number	Farms reporting grain fed cattle marketed by size group - as percent of total 25 %	25-49 %	50-99 %	100-299 %	300-499 %	500 %	Total %
Northwest	8,800	31.2	21.9	21.2	20.4	3.2	2.1	100.0
North Central	5,450	43.8	22.5	18.7	12.9	1.4	0.7	100.0
Northeast	2,705	43.8	24.1	16.3	13.2	1.7	0.9	100.0
West Central	8,363	35.1	22.7	20.1	17.6	2.9	1.6	100.0
Central	7,156	35.9	24.2	20.3	16.6	2.2	0.8	100.0
East Central	6,456	33.6	23.7	22.1	17.6	2.0	1.0	100.0
Southwest	4,940	35.4	24.6	18.2	17.0	3.0	1.8	100.0
South Central	1,936	47.7	26.8	14.6	9.1	1.4	0.4	100.0
Southeast	3,185	45.3	23.7	16.6	12.6	1.4	0.4	100.0
State	48,991	37.0	23.4	19.6	16.5	2.3	1.2	100.0

[a]Source: Ibid.

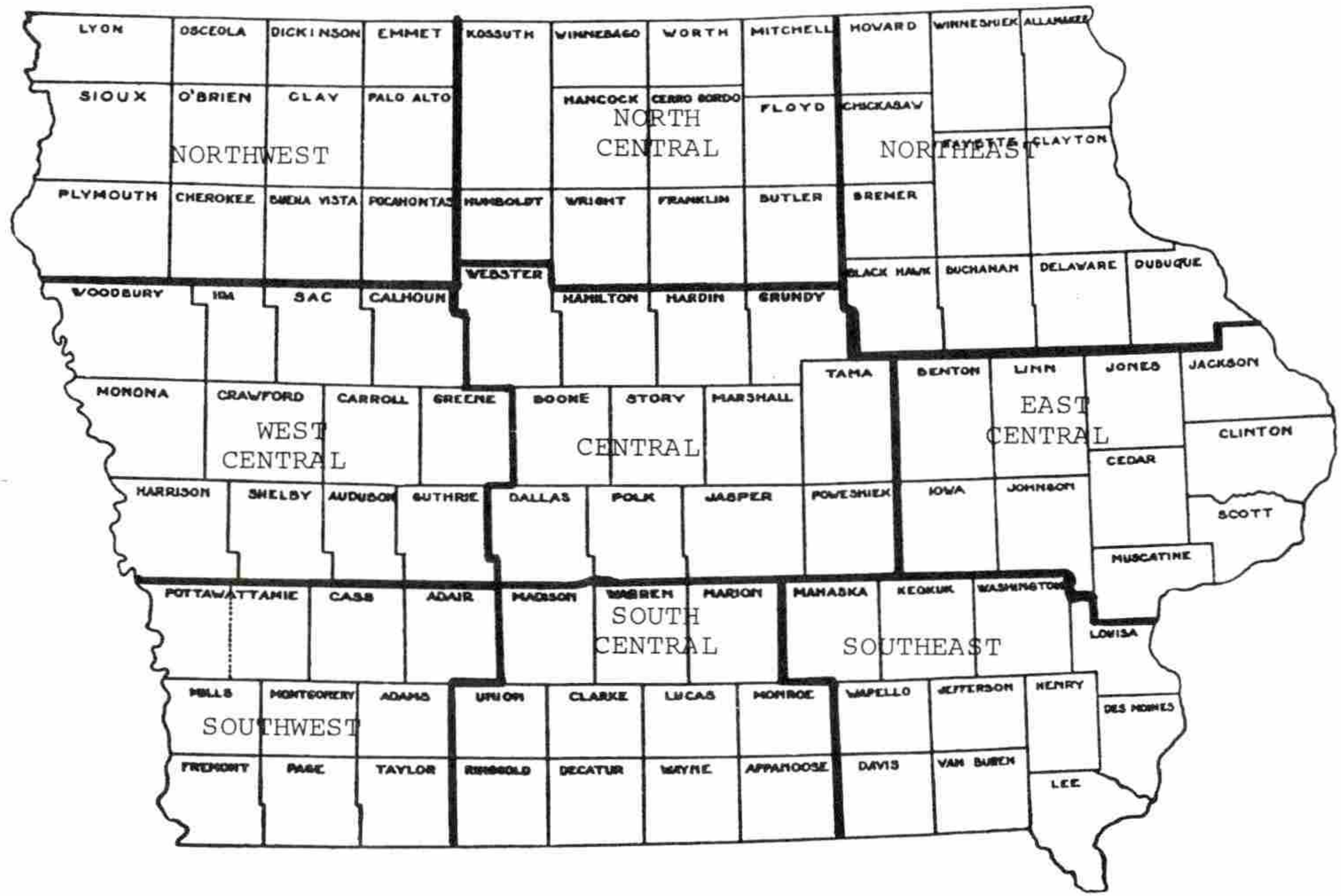

Figure 1. Iowa crop reporting districts - 1965

Snapp and Neuman (23, p. 248), noted animal scientists at the University of Illinois, ascribe the following advantages to the inclusion of a feeder cattle program in the farm organization:

(1) The program affords an opportunity to market at a profit large quantities of both roughages and farm grown grains.

(2) Large profits are occasionally made with this program due to favorable price rises during the period of ownership of a drove of feeder cattle.

(3) A large volume of high fertility manure is produced in this program.

(4) It is a relatively short-time program, making it possible to turn more than one drove of cattle per year in some types of finishing programs, or to finish off a drove of cattle between peak labor requirements in farming operations.

(5) The program is flexible with respect to number, weight, and grade of cattle, as well as to length of feeding period and type of ration fed.

Several of these points will be investigated in this study to determine their validity as reasons for the inclusion of feeder cattle in a farm's production organization. Point 2 is speculative in nature and will not be dealt with in this study. Because of the large volume usage of commercial fertilizers by farmers, point 3 also will not be dealt with in the study as an income generating feature of the cattle feeding enterprise.

Thus, this study has been initiated to investigate the economic forces exerted by the feeder cattle enterprise on the total production organization of the farm. The objective of the farmer feeder will be assumed to be the maximization of net farm income during the accounting year. Linear programming will be used as the methodological tool.

This study is not intended to investigate commercial cattle feeding operations of the type that have developed in the western and southwestern United States in recent years. These operations are characterized by hired labor, bulk purchase of feeds, specialized equipment and specialized management with the sole purpose of feeding large numbers of cattle. The commercial feedlot operator is faced with maximizing net income from one enterprise, cattle feeding. Rather, this study concentrates upon the farmer feeder. The farmer feeder includes feeder cattle as an integral part of many other farm production activities. This gives rise to a host of complex and interrelated management decisions. The farmer feeder is faced with maximizing net farm income from all enterprises of the farm operation, consistent with the resource limitations of the farm.

The specific objectives of this study are:

(1) To determine the competitiveness of the feeder cattle enterprise for the use of an existing set of farm resources.

(2) To determine the optimum mix of farm grown and purchased feeds in the ration fed to the feeder cattle enterprise.

(3) To determine the optimum size of the feeder cattle enterprise within the farm organization under given resource conditions.

FARM PRODUCTION DECISIONS

The theoretical framework for the farm production decisions included in this study is presented in this section. Only the short run production period will be considered with land, buildings and machinery as components in fixed amounts for the farm production plant. The length of the short run planning period for the farmer is the accounting year, which coincides closely with the calendar year. The objective of the farmer is assumed to be the maximization of net farm income for the accounting year. Net farm income includes both the sale of production from the activities and production held in inventory and is defined as a return to previously unpaid capital, labor and management.

The annual costs associated with the fixed resources represent fixed costs to the farm operation but are not relevant costs in decisions made regarding the production activities of the farm for the short run period. Only variable costs are relevant to the choice of the maximum net income combination of production activities.

The production decisions of the multi-product farm firm in the short run revolve around three central questions:

(1) The combination of products and quantity of each product to be produced?

(2) The resource combination and quantity of each resource to be utilized in the production of each product?

(3) The price level of production and resources?

The production activities of the farm firm may be separated in terms of the enterprises (both crop and livestock enterprises considered) with each activity differentiated on the basis of input use, length of production period and/or the final output.

The farmer will exploit any complementary and supplementary relationships between production activities and expand production until a competitive relationship exists between the activities for resource use. The criterion for maximizing net income in the short run is the net price of each production activity where the net price is defined as the difference between the total revenue and total variable costs for the production of one unit of the activity. Net income is at maximum for two activities A and B when the marginal rate of product substitution (MRPS) is equal to the net price ratio of the two products. This criterion may be represented as:

$$\text{MRPS A for B} = P_A/P_B$$

$$\text{or } \Delta B/\Delta A = P_A/P_B$$

where the MRPS A for B is defined as the number of units of B replaced by increasing the production of A by one unit. P_A and P_B represent the net price per unit of the production activities A and B respectively.

Crops represent a primary product of farm production. Crops produced on the farm may also be used as inputs in the production of livestock. Livestock is then considered a secondary product. Heady (6, p. 260) states the relevant production questions regarding primary and secondary products:

> (1) What pattern of primary production will allow a maximum output of the secondary product when resources for the former are limited?
> (2) What quantity of primary product should be sold or purchased if returns through the secondary product are to be maximized?

Assume that a livestock enterprise is to be produced and some combination of grain (G) and forage (F) are to be utilized in the production of the livestock.

The profit maximizing criterion for the production of grain and forage in the crop rotation and marketed through livestock is equating the marginal rate of product substitution (MRPS) of forage for grain in the crop rotation with the marginal rate of product substitution (MRPS) of forage for grain in the production of livestock. This same criterion may symbolically be portrayed as:

$$\Delta G/\Delta F = \Delta G'/\Delta F'$$

where $\Delta G/\Delta F$ represents the MRPS of forage for grain in the rotation and $\Delta G'/\Delta F'$ represents the MRPS of forage for grain in the production of livestock. When the MRPS of forage for grain in the rotation is less than the MRPS of forage for grain in livestock production, the substitution of forage for grain in both the rotation and livestock ration will increase livestock production. The opposite situation would indicate that the substitution of grain for forage in the rotation and ration will increase livestock production.

Equating the MRPS represents the income maximizing criterion for competitive primary and secondary products. The profit maximizing criterion for resource use among competitive production activities is the equating of the marginal value product (MVP) of the resource use in all alternative uses with the price of the resource. Marginal value product is defined as the addition to total product because of an increase use of one more unit of the resource times the price of the product. For two resources X and Y both used in production of products A and B the criterion may be represented as:

$$\frac{MVP_{XA}}{P_X} = \frac{MVP_{XB}}{P_X} = \frac{MVP_{YA}}{P_Y} = \frac{MVP_{YB}}{P_Y} = 1$$

where MVP_{XA} represents the marginal value product of resource X in the production of A, etc. and P_X represents the price per unit of resource X, etc. Inherent in the criterion presented is the assumption that resources are unlimited and profits from any one enterprise or activity are at a maximum.

When resources are limited the profits for any one enterprise may not be at maximum, but the relevant problem becomes maximization of profits from all enterprises on the farm. Maximum net income for the farm is desired and the criterion becomes equalization of the marginal value product with the added dollar cost of increased resource use in that activity.

The price of the farm raised feeds is implicit in the opportunity cost of the feed use among several activities. Opportunity cost represents the income foregone in not using a resource in a given alternative. Consider farm raised feed for use in a livestock ration or as a primary saleable product. The income foregone in not selling the crop represents the opportunity cost or the added dollar cost of using the crop in livestock production.

Livestock production represented by additional weight gain on an animal represents a decision to be made by the farmer regarding the final weight of the livestock or the amount of product to be produced. The marginal criterion is again applicable to the decision in that the profit maximizing criterion is equalization of the price of an additional unit of weight with the marginal cost of achieving the additional weight gain.

This study uses linear programming as a mathematical means for choosing the most profitable combination of production activities and resource use. The net price of each activity is the criterion of choice. Each resource is viewed in terms of its contribution to the value of the program in one production activity as opposed to its value used in other production activities. The linear programming results thus approach equating the MVP of a limiting resource in the production of a product to the dollar cost of that resource or its opportunity cost for use in other production activities. The study concentrates on the number of feeder cattle to be fed and the combination and amounts of feeds to be fed to the cattle. The combination and amounts of inputs used and the amount of final product (per unit of activity) are determined for all production activities except feeder cattle. Feed input usage and the finished weight of each feeder animal were determined in the analysis. Thus, the major production questions investigated in this study deal with feed usage in the production of feeder cattle and the amount of feeder cattle production (number of animals and final weight per animal) that will maximize net income for the farm operation.

REVIEW OF LITERATURE

Several farm planning studies that have included feeder cattle as competitive activities for farm resources will be reviewed in this section. Discussion will be confined to the effect of feeder cattle upon resource use and net income. Of the four studies mentioned in this section, the first three involve the application of linear programming analysis to a specified farm resource base to determine the maximum net income producing mix of production activities. The fourth study is comprised of budget analyses to examine the costs and returns to be expected from different systems of feeder cattle management.

Heady, et al. (8) studied optimum farm plans for beginning farm operators on 160 acre southeast Iowa farms. Three pasture and three drylot cattle feeding activities were considered. Using 1947-54 average adjusted prices for hogs and 1935-54 average adjusted prices for beef, cattle feeding was included in the farm plan only when operator capital availability exceeded $10,000 and then only after labor availability limited further expansion of the hog enterprise. As capital became unlimiting, forages were included in the rotation to be utilized for pasture by the feeder calves. With all activities competing for resource use, 47 head of pasture fed calves and 11 head of deferred fed calves entered the farm plan when capital was unlimiting.

Situations of relatively high and low hog and cattle prices, as compared with the average prices used, showed that cattle feeding was included in the farm plans at all price levels when capital was unlimiting. Fluctuations in hog prices caused a greater variation in net income than did fluctuations in beef prices. But, it must be borne in mind that hog price fluctuations represent changes only in the sale price of hogs. Beef price fluctuations take place in the purchase price of the feeder animal and the sale price of the finished animal with the difference between the two prices (margin) being the major component of a change in net income because of beef price fluctuations.

Mackie et al. (15) studied farm plans for beginning farm operators on 160 acre central Iowa farms. Two management levels, average and above average as reflected in the resource use and production coefficients, were considered. Two drylot cattle feeding activities (calves and yearlings) and one pasture feeding activity (calves) were included in the study. All cattle feeding was included at above average management. Prices used in the study were 1947-54 average adjusted prices for hogs and 1935-54 average adjusted prices for beef. Cattle feeding activities entered the farm plan only after operator capital availability exceeded $15,000. With $15,000 capital and all other production activities included with average management, 16 drylot fed calves and 19 pasture fed calves were included in the farm plan but only after the spring pig activity was limited by building space. A situation of relatively low hog prices, compared with the average prices used for other farm production, showed that feeder cattle were included in the farm plan only after all other production activities were included with average management. Including feeder cattle in the farm plan did not reduce the uncertainty associated with price fluctuations. When only short term hog price declines are expected, the authors concluded there would probably be no reallocation of resources to feeder cattle.

Rhoade, et al. (21) investigated farm plans for a 300 acre central Indiana farm. The livestock activities included 40 different feeder cattle systems with 1947-57 average adjusted prices used for both hogs and cattle. When all activities competed for resource use, results showed labor income to be the highest when the maximum number of hogs were farrowed under a farrowing building capacity restraint and 265 medium long yearlings were fed on corn silage. Labor income was $36,400 with a capital requirement of $180,300 for the farm operation. Hog enterprises were shown to have priority for resource use over cattle feeding enterprises. When only hog enterprises were considered, the labor income was reduced by $4,800 and the capital requirement reduced by $40,000. Labor income was $31,400 (or remained about the same as the plan that considered only hog enterprises) when feeder cattle were the only livestock enterprise considered but the capital requirement increased to $270,700, which is substantially higher than the first two plans computed. Sixty choice calves, 225 two year old steers and 638 medium two year old yearlings, all fed on corn silage, were included in the farm plan.

Suter and Washburn (27) developed budget cost and return estimates for 28 different systems of feeder cattle management using secondary data sources and 1947-57 average cattle prices. Economies of scale and farm operator management levels were not considered in the study. Some major observations made about cattle feeding in the study were:

(1) The kind of cattle fed, referring to the age, quality and sex of the cattle, should correspond to the feed availability on the farm. Higher quality and younger cattle consume more concentrates while lower quality and older cattle consume more roughages.

(2) The price that can be paid for feeder cattle, in order to obtain a profit, depends to a large extent on the current corn and other feed prices and the future expected price of finished cattle.

(3) Assuming a higher purchase price per pound than sale price per pound for cattle, a narrower price margin is necessary for older and heavier cattle than for younger and lighter cattle in order to have profitable feeding. As beef price levels increase,

profitable cattle feeding is still attained at wider price margins than at lower beef price levels.

(4) The price relationship between feeder and finished animal had the greatest influence on returns from any feeder system budgeted.

The first three farm planning studies reviewed showed that the inclusion of feeder cattle in the farm plan required high levels of production and fixed capital in relation to the farm size. Also, feeder cattle were included in the farm plan only after resource restrictions prevented further expansion of the crop and swine enterprises.

This study will examine the effect of the feeder cattle enterprise on resource allocation with the use of linear programming analysis. Capital availability will be unlimited with an opportunity interest charge of 7% placed on all capital used. Competitive hog activities are included in the study with limitations on the building space available to the hog enterprise. Thus this study will concentrate on the farmer feeder who is not limited by a given amount of available capital. Hog enterprises are restricted to prevent their utilization of the farm resources to the extent that the feeder cattle enterprise is excluded from the farm plans.

The price levels for all inputs and products are held constant in this study. The price margins for calves and yearlings are also held constant.

The major deviation of this study from the four studies reviewed comes in regard to the feed resource usage of the feeder cattle enterprise. The feed consumption mix and amount for the feeder cattle activities in the studies reviewed was predetermined for each activity. This study endeavors to examine both the profitability of including feeder cattle in the farm plan and the feed consumption mix and amount that will allow the feeder cattle activity to be most profitably included in the farm plan. The studies reviewed examined the competitive position of feeder cattle activities given the feed requirements for the activity. This study will examine the competitive position of the feeder cattle activities in the use of farm resource and the competitive position of available farm raised and purchased feeds in their usage by the feeder cattle activities. The net energy system of evaluating cattle requirements and feed contents will be utilized to determine the competitive position of feed usage by the feeder cattle.

METHODOLOGY

The emperical technique of linear programming has gained widespread usage in industry as a mathematical procedure for determining optimum input-output combinations in the attainment of given objectives. The application of linear programming to farm planning has increased also. The development of electronic computers with the capability of processing a large number of variables with high speed and accuracy have made this method of farm planning usable. The technique of linear programming and the major assumptions embodied in the technique are discussed extensively by Heady and Chandler (7). Guidelines for the application of linear programming to farm planning and the construction of farm planning models are discussed by Beneke (2). This study will not repeat this development.

This study focuses upon the influences exerted by the feeder cattle enterprise upon farm resource use and net farm income. Major emphasis is placed upon the determination of the feed mix to be fed the cattle enterprise. Thus, this study will seek to determine least-cost feed combinations while selecting an optimum set of enterprises to maximize income.

Several linear programming alternatives exist for determining the least cost mix of feeds to be fed to feeder cattle. Linear programming has been widely utilized to determine a least cost mix of feeds by considering the nutritional requirements of an animal and the feeds available -- the price per unit of feed being the criterion for choice of the feed mix. This analysis considers the animal as completely independent from other farm production activities, ignores to some extent the alternative uses of the feeds and ignores completely the alternative opportunities of resources used to produce and distribute any farm grown feeds. Also, linear programming analysis has been widely used to select between different cattle feeding activities with the selection of the most profitable activities made on the basis of different feeding plans for the cattle. Feeding plans may be differentiated by feeds, amount of feed or period during which a feed is fed. The use of linear programming in this study seeks to combine the least costing and profit maximizing analyses for feeder cattle enterprises.

Linear programming was employed in this study to determine the mix of crop and livestock activities that would achieve maximum net farm income for the farmer, consistent with the given resource base of the farm. An owner-operator situation was assumed. The feed mix to be fed the feeder cattle enterprise and amounts of each feed were determined within the model with both the number of feeder cattle and the feed mix as variables in the model. The net energy and protein requirements of the feeder animal served as minimum nutritional restraints to be satisfied by the available cattle feeds.

Thus the model constructed served to determine the combination of production activities that would maximize net farm income[1] and the mix of feeds that would fulfill the nutritional requirements of the feeder cattle with minimum sacrifice to net farm income.

A hypothetical farm situation was constructed to which the linear programming analysis was applied. The farm situation constructed was not intended to represent any particular farm but coefficients used were intended to reflect typical conditions for the area. A variety of reliable data sources were consulted to develop the resource base of the farm and the input-output coefficients used in the model. Primary sources of crop production data and fertilization rates were obtained from Iowa State University reports from experimental farms (1) and the Department of Agronomy (11). Machinery and equipment operating costs and crop labor coefficients were obtained from data collected by

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[1]Maximization of net farm income is for the short run period with certain resources assumed as given.

James (12), Suter (25) and Van Arsdall (31). Input-output coefficients for the swine enterprise were obtained from data gathered in a study by Trede (29). Labor coefficients for the feeder cattle enterprise were taken from information in studies by Knight and Bortfeld (13) and Van Arsdall (30). Labor and cost coefficients for processing and distributing cattle feeds were obtained from data collected by Suter (24), Thompson, et al. (28) and Van Arsdall (30). Investments in facilities and the annual costs associated with these investments for cattle feeding, swine and machinery storage were obtained from data and information gathered by James (12), Trede (29) and Van Arsdall (32).

THE STUDY FARM

A hypothetical farm situation was employed in order to evaluate the consequences of including feeder cattle in the farm production plans. The farm was assumed to be owner-operated with the land and equipment and facilities for both crop and livestock enterprises as given resources.

Resources, Equipment, Facilities

Land

The land resource for the farm was assumed to be 400 acres located in the Galva-Primghar-Sac Soil Association Area. Tillable land included 385 acres capable of sustaining continuous row crop production. Farmstead, lanes and waste included 15 acres.

Labor

The owner-operator furnished most of the labor with additional part time labor available for both crop and livestock activities. No full-time labor was employed. Table shows the breakdown of operator labor availability. Operator labor availability includes reductions for overhead labor required during each period. A maximum of 400 hours of part-time labor were available for the year at $2.00 per hour.

Table 6. Operator labor available by period

Period	Months included	Operator labor available (hours)
DJF	December, January, February	825
MAM	March, April, May	1,035
JJA	June, July, August	875
SON	September, October, November	1,050

Capital

Capital was assumed to be a non-limiting factor in the farm operation. Capital coefficients were developed for each activity based on the operating capital used by the activity and the average time span of capital employment in the activity. A 7% interest charge was made against all operating capital used in the operation.

Fixed capital resources assumed as given were land, buildings and machinery. The annual costs of depreciation, taxes and interest associated with these resources were deducted from the value of the program to estimate net farm income but were not included in the linear programming analysis.

Crop machinery

The farm operator owned adequate tillage equipment for seedbed preparation as well as a full compliment of four-row planting and cultivating equipment. Harvesting equipment owned included a forage chopper with appropriate attachments for harvesting windrowed crops or standing row crops, and a corn picker for harvesting ear corn. Combine usage for harvesting soybeans or corn was included in the model on a custom hired basis.

Crop storage

Adequate storage facilities were existent for any volume of grain or hay that might enter the farm plan based on the maximum amount of storage needed in conjunction with the livestock facilities existent on the farm. A silage storage capacity of 300 tons (90% d.m.) was included in the model. This is equivalent to the capacity of three concrete stave silos, 18 feet X 50 feet.

Swine facilities

Adequate swine facilities were available to farrow 40 sows and finish the litters to market weight.

Cattle facilities

Cattle facilities to accommodate 500 head of feeder cattle on the farm at any one time were available.

Fenceline bunk cattle feeding facilities, utilizing a tractor drawn self-unloading wagon, were assumed.

Crop Activities

Crop production activities were divided into growing, harvesting and dispensing, each being a different activity in the model.

Crop growing activities included planting the crop and subsequent maturing of the crop. The several crop growing activities (rotations) included in the model were:

Continuous corn (fall plowed)
Continuous corn (spring plowed)
Corn-soybeans (fall plowed)
Corn-soybeans (spring plowed)
Corn-oats-meadow-meadow
Corn-oats-meadow
Sorghum-corn-oats-meadow

The continuous corn and corn-soybean rotations were differentiated by the seasonal labor requirements for plowing. Spring plowing was assumed for all other rotations. Meadow rotations were comprised of a grass-legume mixture.

Crop harvesting activities included harvesting the crop and storing it within the existent facilities on the farm. Table 7 indicates the harvesting options for the various mature crops.

Activities were included for marketing corn grain at $1.00 per bushel and oat grain at $.70 per bushel. Baled hay could be sold at $20.00 per ton. These were assumed to be net market prices at the farm and hence no marketing labor was required.

Table 7. Crop harvest options

Crop	Harvest option	Machine used
Corn	Ear corn	Owned picker
	Shelled corn	Custom combine
	Silage	Owned chopper
Oats	Grain	Custom combine
	Silage	Owned chopper
Hay	Baled	Custom baler
	Haylage	Owned chopper
Sorghum	Silage	Owned chopper
Soybeans		Custom combine

Farm produced feeds available to the livestock enterprises included:

Corn silage (3-4 lb. urea added per ton, 90% d.m.)

Ground shelled corn

Ground ear corn

Oat silage

Baled hay

Sorghum silage

Haylage

Feeds also available for purchase from off-farm sources included:

Shelled corn at $1.05 per bushel

Baled hay at $21.00 per ton

Soybean oilmeal at $94.00 per ton

Livestock Activities

Swine

Two 2-farrowing swine systems were included in the model with hogs finished to market weight in partial confinement housing. A winter-summer farrowing system and a spring-fall farrowing system were developed. The only feed requirement evaluated for the swine activities was ground shelled corn. All other swine feed was considered in the net selling price of the swine activities.

Feeder cattle

Feeder cattle activities were constructed for the study by specifying the nutritional needs of the animal during the growth and finishing periods with primary emphasis upon the net energy and protein requirements of the animal. Feeder cattle activities were defined to include the purchase, growth-finish and sale of one animal.

The following items were established for each feeder animal included in the model in order to ascertain the nutritional requirements of activity:

Sex

Initial weight

Average daily gain over the period

Final weight

Activities were developed in the model for steers only. Purchase weight options of 430 lbs. (calves) and 645 lbs. (yearlings) were included. Assuming a seven percent shrink from market to the feedlot, the in-feedlot weights were 400 lbs. and 600 lbs. respectively. Calves could be purchased only in December, whereas yearlings could be purchased in December and June.

The production of beef may be viewed as having a variable length of production period. The average daily gain and the final weight become the physical variables that determine the length of the production period. The average daily gains for feeder cattle in this study were specified for each activity. The feed choice thus becomes dependent upon the nutritional needs of the animal for maintenance (body weight) and production (average daily weight gain).

The average daily gain specified in the model assumed a given or fixed genetic production potential of the animal. It must be recognized that average daily gains vary with the weight of the animal. Average daily gains that represent less than the production potential of the animal may be considered subjective restraints imposed on the animal by the farmer feeder and/or environmental conditions and may cause a reduction in net farm income from that attained by the potential gain of the animal. Two average daily gain schedules were developed for this study as shown in Table 8.

Table 8. Average daily gains assumed for steers during specified weight intervals

Live weight (lbs.)	ADG (lbs./day) A	B
400- 600	1.75	2.25
600- 700	2.25	2.75
700-1050	2.75	3.25
(ADG 400-1050 lbs.)	(2.33)	(2.83)

The total production from the feeder cattle activities was included in the model via two means, the number of cattle fed and the final weight of the cattle. Two finished weight alternatives were included for each feeder activity with finishing at 1000 lbs. or 1050 lbs. Assuming a 4% in-transit shrink to market, these represent sale weights of 960 lbs. and 1008 lbs., respectively.

FEEDER CATTLE NUTRITIONAL REQUIREMENTS

Net Energy System

The development of a system for expressing the net energy requirements of beef cattle and content of feeds has given rise to a new measure for determining the least cost, profit maximizing mix of feeds to grow and finish beef cattle. Net energy is defined to be the energy remaining for use by the animal after deducting the energy lost to digestion and metabolism from the metabolizable energy available to the animal. (Metabolizable energy is that energy remaining for use by the animal body after energy losses in the feces, urine and gas are deducted from the gross energy intake of the animal.) Net energy is expressed in calories.

A new system for expressing net energy values was developed by Lofgreen (14) of the University of California, Davis. This system separates the net energy animal requirements and feed values into two components -- maintenance and production. Maintenance of the animal body includes net energy used for maintaining the body temperature and continuation of the body life processes. Use of net energy for production refers to the deposition of body tissue and fat that make up weight gain for the animal. The composition of this weight gain is primarily body tissue and muscle in younger animals while it is primarily fat in older and heavier weight animals.

Lofgreen (14, p. 793) discusses the separation of net energy into two values as a more accurate system of expressing net energy values than is a single net energy value for both maintenance and production. The single net energy value for a feed will vary depending upon the level to which the feed is fed and other environmental factors, while the separate net energy values for maintenance and production are more nearly constant figures, independent of the feeding level and environmental factors. Also, because roughages produce considerably more energy during digestion in relation to concentrates, they are a relatively more valuable part of maintenance rations than are concentrates. Separation of the maintenance and production energy components then gives roughages a more favorable position in meeting the maintenance requirements of an animal. The new net energy system therefore, tends to overcome the criticism that a single net energy value does not give roughages a larger value for maintenance than for production in relation to concentrates.

Net energy for maintenance (NEm) is defined to be that amount of energy equal to the heat produced by a fasting animal. Lofgreen determined, with the use of comparative slaughter trials, a linear relationship to be existent between heat production in an animal's body and the metabolizable energy intake by the animal. NEm was then determinable as the heat production by the animal at zero metabolizable energy intake. Lofgreen (14, p. 795) found that the NEm requirement per unit of metabolic body weight for steers and heifers did not differ significantly and may be expressed as

$$NEm = 0.077W^{0.75}$$

where NEm is megacalories per day and W is bodyweight in kilograms.

The NEm values of various feedstuffs were then able to be determined from the established metabolizable energy-heat production relationships as the amount of feed intake required to produce the heat of a fasting animal.

Net energy for production (NEp) is defined as the energy stored in new body protein or fat as a result of feed consumption above that required for maintenance. With the use of difference trials, Lofgreen (14, p. 799) was able to determine the increase in heat production in an animal's body due solely to an increased consumption of a specified ration above the amount of the ration required for maintenance. Equations were then developed to express the relationship between the retained energy and the weight gain. The relationships determined were:

$$NEp = (52.72g + 6.84g^2)\ (W^{0.75})$$

$$NEp = (56.03g + 12.65g^2)\ (W^{0.75})$$

for steers and heifers respectively where NE_p is expressed in kilocalories, g is daily weight gain in kilograms and W is body weight in kilograms.

From the data obtained in the difference trials, Lofgreen and Garrett were able to determine the NEp values of the specific rations that were fed. The NEp values were determined by measuring the difference in energy gain for two levels of feeding above that required for maintenance and calculating the difference in energy gain per unit of the feed.

As the result of net energy experiments and trials, NEm and NEp feed values and animal requirements have been reported by Lofgreen and Garrett in the 1967 California Feeders Day Report (3). It must be recognized that not all NEm and NEp data reported were developed directly from feeding trials. Some feed values reported were estimated from experimentally determined relationships with metabolizable energy and total digestable nutrient values reported in the N.R.C. Beef Cattle Bulletin (18) and by Morrison (17).

The net energy system will thus serve the dual role in this study of defining two of the nutritional requirements of the feeder cattle activities and determining the diet of feeds to be fed to the cattle enterprise.

Net Energy Requirements

The net energy maintenance and production requirements for growing and finishing steers were obtained from University of California data(3). Maintenance and production requirements were given on a per day basis for various body weights and average daily gains. It was assumed these per day requirements would remain constant over 10 lb. weight gain intervals of the animal. The net energy requirements per head for any 10 lb. weight gain interval are then determined to be:

NEM (10 lbs. gain) = NEm X 10 lbs./lbs. gain per day

NEP (10 lbs. gain) = NEp X 10 lbs./lbs. gain per day

where NEM and NEP represent the per day requirements of maintenance energy and production energy respectively for steers of a given body weight and achieving a given daily rate of gain. Net energy requirements (maintenance or production) for an entire weight gain interval (given the body weight and average daily gain of the animal) are the sum of the net energy requirements for the 10 lb. weight gain intervals contained in the desired gain interval.

Protein Requirements

Protein is a vital constituent of the animal body and used for both maintenance and growth. A third nutritional restraint included in the model was the crude protein requirement of the feeder cattle. Research by Preston (19) has led to the development of crude protein requirements of feeder cattle expressed in the following equation:

$$C.P. = 5.86W^{0.75} (1 + 0.924G)$$

where C.P. represents grams of crude protein, W is the animal's body weight and G is the daily rate of gain, both in kilograms. Thus, crude protein requirements, as with net energy requirements, may be expressed as a function of the animal's body weight and average daily gain.

Table 9 indicates the total requirements for net energy maintenance and production and crude protein for steers in each of the specified weight changes.

Other Nutritional Requirements

Dry matter consumption

The amount of feed that an animal may consume at any one time represents a physiological restraint that cannot be ignored. While it is desirable to feed cattle to their capacity to satisfy their hunger, there also exists a consumption maximum for each animal. The consumption maximum of an animal will vary and should increase with both age and weight. Maximum consumption per head per day of 90% d.m. feed was defined for this study as 2.25% and 2.50% of the body weight of the animal. Tables 10 and 11 indicate the maximum amount of 90% d.m. feed that an animal may consume over a specified weight interval and at a specified average daily gain for that interval.

Bulk refers to the relative weight of a given volume of feed. Including roughages, with their high fiber content, increases the bulk in a ration. While a minimum of bulk is desirable in the ration to provide distention of the rumen

Table 9. Total requirements of NE_m[a], NE_p[b], and crude protein[c] for growing and crude protein[c] for growing and finishing steers in given live weight intervals for different average daily gains

ADG (lbs./day)	Per head 1.50			1.75			2.00			2.25		
Weight (lbs.)	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.
400- 500	278	140	76	238	142	70	208	143	64	185	145	60
500- 600	324	163	88	277	165	81	243	167	75	215	169	70
600- 700	367	185	100	315	187	91	275	189	85	245	192	80
700- 800	409	206	112	351	208	102	307	211	95	273	214	89
800- 900	450	226	122	385	229	112	337	232	104	300	235	98
900- 950	240	121	65	205	122	60	180	124	56	160	125	52
950-1000	250	125	68	214	127	62	187	129	58	166	130	54
1000-1050	259	130	71	222	132	64	194	134	60	172	135	56
	2.50			2.75			3.00			3.25		
	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.	NE_m	NE_p	C.P.
400- 500	167	147	58	152	149	55	139	151	53	129	153	51
500- 600	194	172	67	177	174	64	162	175	61	150	178	59
600- 700	220	194	75	200	197	72	184	199	70	170	202	67
700- 800	246	216	84	223	220	80	204	222	77	189	225	75
800- 900	270	238	92	246	241	88	225	244	87	208	247	82
900- 950	144	127	49	131	129	47	120	130	45	111	131	44
950-1000	150	132	51	136	134	49	125	135	47	115	137	46
1000-1050	155	137	53	142	139	51	130	141	49	120	143	47

[a]Net energy, maintenance, expressed in megacalories, source: California (3).

[b]Net energy, production, expressed in megacalories, source: California (3).

[c]Expressed in pounds, data generated by Iowa State University, Department of Animal Science, based on work by R. L. Preston (19).

Table 10. Maximum consumption of dry matter feed by cattle for different average daily gains during given weight intervals - 2.25%[a]

Body weight/ADG (lbs./day) (lbs.)	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
	(lbs. 90% d.m. feed)							
400- 450	318	272	239	212	191	174	160	147
450- 500	356	304	267	237	214	194	178	165
500- 550	393	337	295	262	236	215	197	182
550- 600	431	368	323	287	259	235	216	199
600- 650	468	401	352	312	281	256	235	217
650- 700	504	431	378	336	302	275	252	233
700- 750	543	465	408	362	326	297	272	252
750- 800	581	497	436	387	349	317	291	269
800- 850	618	529	464	412	371	338	310	286
850- 900	656	561	492	437	394	358	329	303
900- 950	693	593	520	462	416	379	348	321
950-1000	731	625	548	487	439	399	366	338
1000-1050	768	657	576	512	461	420	385	356

[a]Expressed as 2.25% of the average live weight of the animal during the weight gain interval.

Table 11. Maximum consumption of dry matter feed by cattle for different average daily gains during given weight intervals - 2.50%[a]

Body weight (lbs.)/ADG (lbs./day)				(lbs. 90% d.m. feed)				
	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
400- 450	353	303	265	235	212	193	177	163
450- 500	396	340	297	264	238	217	199	183
500- 550	436	375	328	291	262	238	219	202
550- 600	480	412	360	320	288	262	241	222
600- 650	520	446	390	346	312	284	261	240
650- 700	563	483	423	375	338	308	282	260
700- 750	603	518	453	402	362	330	303	279
750- 800	646	555	485	431	388	353	324	299
800- 850	686	589	515	457	412	375	344	317
850- 900	729	626	548	486	438	399	366	337
900- 950	769	661	578	513	462	420	386	356
950-1000	813	698	610	542	488	444	408	376
1000-1050	853	732	640	568	512	466	428	394

[a]Expressed as 2.50% of the average live weight of the animal during the weight gain interval times the number of days in the interval.

and slow material passage through it, no minimum restraint was included in the model for bulk. The bulk restraint for feeder cattle in this study was defined as a percentage of the maximum consumption of the animal, where the amount of 90% d.m. roughage fed during a period may not exceed a given percentage of the total feed consumption during the period. Bulk feeds were allowed to comprise up to 50% of the total feed consumption during all periods in the study. Roughage feeds included corn silage (50% roughage), ground corn cobs, oat silage, hay, sorghum silage and haylage.

Bulk as a maximum restraint must be recognized as a subjective restraint imposed by the farmer. The percentage of bulk in the feed mix affects the finished grade of the animal and thus the price received. Thus, even though a high bulk ration may be cheaper to feed it is not always the most profitable.

ACTIVITIES TO SUPPLY CATTLE FEED

The net energy system also was used in this study to determine the combination and amounts of feed needed to meet the feeder cattle net energy requirements for maintenance and production with least sacrifice to the value of the program. The construction of feed activities to meet the animals net energy maintenance and production requirements will be discussed in this section.

If the net energy maintenance and production requirements of one feeder animal are determined to be NEM and NEP, respectively, the total amount of a given feed, j, needed to fulfill these requirements is:

$$\frac{NEM}{NEMj} + \frac{NEP}{NEPj} = A$$

where NEMj and NEPj are the per unit net energy maintenance and production contents of feed j, respectively, and A is the number of units of feed j to be fed. The total amount of the feed that must be fed to satisfy the animal's net energy requirements is the summation of the amount of the feed needed to fulfill the maintenance requirement and the amount needed to fulfill the production requirement.

As a vehicle for satisfying the net energy requirements of the feeder cattle, activities were constructed for each available cattle feed. Two separate activities were constructed for each feed -- one activity to fulfill the maintenance requirement and the second activity to fulfill the production requirement. The total amount of the feed fed is the summation of the two activity levels.

The inclusion of the net energy maintenance and production values of the feed in the same activity would erroneously indicate that one unit of the feed would simultaneously fulfill the maintenance and production requirements of the animal.

Along with the two activities constructed for each feed, a separate row was included for each feed to cause a contingency of the two activities upon each other. Failure to include this between the two activities would result in the independent evaluation of a feed for maintenance and for production purposes. The obvious result would be the usage of the feed providing the greatest number of megacalories of maintenance energy per dollar cost to fulfill the maintenance requirements and, likewise, the usage of the feed providing the greatest number of megacalories of production energy per dollar cost to fulfill the production requirements of the animal. Each feed must be evaluated as providing both maintenance energy and production energy in the formulation of the diet to be fed.

Figure 2 suggests the construction of activities for a feed. PF1 and PF2 are defined as a given unit of the same feed, j, and X represents the cost per unit of the feed.

	PF1	PF2
RNEM	$-NEM_j$	
RNEP		$-NEP_j$
RCP	$-CP_j$	$-CP_j$
RNEX	NE_{j1}	$-NE_{j2}$
C	-X	-X

Figure 2. Construction of feed activity

PF1 supplies NEM_j megacalories of maintenance energy to row RNEM per unit of feed and PF2 supplies NEP_j megacalories of production energy to row RNEP per unit of feed (90% dry matter basis). Row RCP is utilized to supply the crude protein contents of the feed to meet the animal requirements.

Row RNEX indicates the dependency of activity PF1 upon PF2. This dependency arises because net energy production requirements are a function of both the average daily gain and the weight of the cattle, while net energy maintenance requirements are a function of only the weight of the animal. Each feed is then evaluated upon its competitive position as a supplier of the production energy needs of the cattle and consequently a supplier of the maintenance energy needs of the cattle.

The magnitude of the coefficients in row RNEX indicates the percentage of the feed that will be utilized to fulfill the maintenance requirements of the cattle. Table 12 contains the coefficients used to specify the various percentages.

The adjustment of coefficient NE_{j2} until there is no excess maintenance energy and production energy going unfed to the cattle. This adjustment may be made when row RNEM, RNEP and RCP are less than or equal to ($\leq$) inequalities and row RNEX is and equality (=). Excess maintenance energy or production energy will appear slack. The NE_{j2} coefficient used for any one period is the same for all available feeds in that period.

Table 12. NE_{ijk1} - NE_{ijk2} coefficients expressing the percentage of feed fed to fulfill maintenance requirements (NE_{ijk1} coefficient is assumed to be one)

NE_{ijk2}	Percent of total feed for maintenance
1.000	50.0
0.980	49.5
0.961	49.0
0.942	48.5
0.923	48.0
0.905	47.5
0.887	47.0
0.869	46.5
0.852	46.0
0.835	45.5
0.818	45.0
0.802	44.5
0.786	44.0
0.770	43.5
0.754	43.0
0.739	42.5
0.724	42.0
0.709	41.5
0.695	41.0
0.681	40.5
0.667	40.0
0.653	39.5
0.639	39.0
0.626	38.5
0.613	38.0
0.600	37.5
0.587	37.0
0.575	36.5
0.562	36.0
0.550	35.5
0.538	35.0
0.527	34.5
0.515	34.0
0.504	33.5
0.492	33.0
0.481	32.5
0.471	32.0
0.460	31.5
0.449	31.0
0.439	30.5
0.429	30.0

The NE_{j2} coefficients used in this study were calculated for 0.5% intervals. The quantities and percentages of each feed being fed are then not precise, but offer a realistically accurate answer to the feed mix and quantity to be fed evaluated by means of the net energy system[1].

Given the specified nutritional contents of available feeds and the per head feeder cattle nutritional requirements of minimum net energy for maintenance, minimum net energy for production, minimum crude protein, maximum 90% dry matter consumption and maximum 90% dry matter roughage consumption the feed mix and quantity to be fed to cattle during any period of time (weight gain interval and average daily gain given) is determined as the simultaneous solution to the following equations.

$$\sum_{j=1}^{f} X_{ijk1}(-NEM_j) + Y_{ik}(NEM_{ik}) \leq 0$$

$$\sum_{j=1}^{f} X_{ijk2}(-NEP_j) + Y_{ik}(NEP_{ik}) \leq 0$$

$$\sum_{j=1}^{f} X_{ijk1}(-CP_j) + \sum_{j=1}^{f} X_{ijk2}(-CP_j) + Y_{ik}(CP_{ik}) \leq 0$$

---

[1]The imprecision referred to results because of the 0.5% adjustment interval used and the evaluation of rows RNEM, RNEP and RCP as inequalities (≤) rather than equalities (=). The use of equalities for all rows indicated results in large basis changes in the L.P. solution as NE_{j2} coefficients are adjusted.

$$\sum_{j=1}^{f} X_{ijk1}\,(CN_j) + \sum_{j=1}^{f} X_{ijk2}(CN_j) + Y_{ik}(-CN_{ik}) \leq 0$$

$$\sum_{j=1}^{f} X_{ijk1}\,(RH_j) + \sum_{j=1}^{f} X_{ijk2}(RH_j) + Y_{ik}(-RH_{ik}) \leq 0$$

$$\begin{aligned} NE_{i1k1} - NE_{i1k2} &= 0 \\ NE_{i2k1} - NE_{i2k2} &= 0 \\ &\vdots \\ NE_{ijk1} - NE_{ijk2} &= 0 \end{aligned}$$

Where $X_{ijk1} + X_{ijk2}$ is the total amount of the jth feed fed to the ith group of cattle during the kth time period.

X_{ijk1} = number of units of the jth feed fed, for maintenance purposes (1), to the ith group of feeder cattle during the kth time period.

X_{ijk2} = number of units of the jth feed fed, for production purposes (2), to the ith group of feeder cattle during the kth time period.

NEM_j = megacalories of NEm per unit of the jth feed (90% d.m. basis).

NEP_j = megacalories of NEp per unit of the jth feed (90% d.m. basis).

CP_j = pounds of crude protein per unit of the jth feed (90% d.m. basis).

CN_j = pounds of 90% dry matter per unit of the jth feed.

RH_j = pounds of 90% dry matter roughage per unit of the jth feed.

Y_{ik} = number of head of the ith group of cattle fed during the kth time period.

NEM_{ik} = megacalories of NEm required per head by the ith group of cattle during the kth time period for a specified live weight gain interval during the period. (Implicitly the average daily gains of the animal are known over the weight interval.)

NEP_{ik} = megacalories of NEp required per head by the ith group of cattle during the kth time period for a specified live weight gain interval during the period.

CP_{ik} = pounds of crude protein required per head by the ith group of cattle during the kth time period for a specified live weight gain interval during the period.

CN_{ik} = maximum pounds of 90% dry matter feed that may be consumed per head by the ith group of cattle during the kth time period for a specified live weight gain interval during the period.

RH_{ik} = maximum pounds of 90% dry matter feed that may be consumed per head by the ith group of cattle during the kth time period for a specified live weight gain interval during the period.

NE_{ijk1}, NE_{ijk2} These two coefficients (of opposite sign) express the relationship between X_{ijk1} and X_{ijk2} and indicate the percentage of the jth feed that is used to fulfill the maintenance requirements and the percentage of the same feed that is used to fulfill the production requirements of the ith group of cattle during the kth time period for a specified live weight gain interval on each animal during the period. The NE_{j2} coefficients are the same for all feeds considered during the ith time period and the adjustment of these values must be simultaneous for all feeds until the restraint is satisfied. Thus, the percentage of X_{ijk1} in the ration and the percentage of X_{ijk2} in the ration is equal to 100% of the jth feed used in the ration. As well, these same percentage values of X_{ijk1} and X_{ijk2} indicate the percentage of the total ration utilized for maintenance and production, respectively, during the kth time period.

LIMITATIONS

Inherent in the assumptions and data used in this study are limitations that must be recognized. These limitations do not render the methodology of the study invalid but rather serve to point out results that must yield to cautious interpretation and give impetus to further research and data collection that may be required.

Coefficients used in activities included in the model were derived from various sources of reliable data but do not necessarily reflect the coefficients for all farm situations in northwest Iowa. Coefficients included in the model reflect a high level of management for both crops and livestock.

Net energy requirements for livestock were obtained from data accumulated by Lofgreen and Garrett (14) in trials conducted in California. The validity of these data in accurately reflecting climatic stress periods existant in the Midwest has not conclusively been determined. Failure of these net energy requirement data to reflect these stresses would result in an underestimation of the feed requirements during the feeding period.

The net energy and protein contents of feeds were included in the model as constant coefficients for each feed. It must be recognized that the nutritional content of a feed is subject to some variation not reflected in this study. These variations in net energy and protein contents of a feed may arise as a result of harvest timing, storage facilities and treatments and storage time elapsed until the feed is fed.

The level of a feed being fed and the combination of feeds it is fed in conjunction with and their respective levels were assumed to have no effect on the net energy and protein content or availability for digestion of that feed. Thus the net energy and protein values of a feed were assumed to be linear additive and independent of the feed combination being fed, both assumptions that must be borne out by additional research.

The feeds to be fed and the amounts of each were determined for three month periods during the growing and finish of the feeder cattle. The answers obtained do not then necessarily reflect a daily ration that is to be fed, such as would be determined by dividing the amounts of each feed fed during the period by the number of days in the feeding period. Rather, the ration components are determined and only an "average" ration for the period may be projected from the results.

The feeder cattle activities were constructed with one animal as the unit of the activity. The feeder cattle were then assumed to be a homogeneous group. In actuality, variation in size, rate of gain and feed conversion will exist between animals in any given group of cattle because of genetic, environmental and health differences. Not reflected in this study is the effect these within-group variations may have on the mix and amount of feed fed.

PROGRAMMING RESULTS AND ANALYSIS

The results of the linear programming analyses are presented in five solutions or farm plans with comparison between the solutions lending insight into the economic forces exerted by the feeder cattle enterprise on the farm production organization.

The crop and swine activities previously discussed were allowed to compete for resource use in all farm plans. One feeder cattle activity was allowed to compete for resource use in four of the plans developed. The nature of the feeder cattle activity was changed between plans with differentiation between feeder activities based on initial weight, average daily rate of gain and dry matter consumption of the animals. Prices used in the study were held constant between solutions. Thus, comparison of the solutions obtained indicates the effect on the farm production organization and net income of (1) excluding feeder cattle from the farm organization and (2) varying the initial weight, average daily gain and consumption characteristics of the feeder cattle. The number of feeder cattle fed and the combination and amounts of feed fed were variables in all solutions that included feeder cattle.

A brief description of the feeder cattle activity included in each solution is presented to indicate the nature of the feeder cattle activity investigated. Swine activities were allowed to compete in all solutions with market hogs (220 lbs.) sold at $16 per cwt.

Solution I allowed only crop and swine activities to compete for farm resource use. The results of solution I thus serve as the benchmark for comparison with plans that do include feeder cattle as a competitive activity.

Solution II included steer calves purchased at 400 lbs. in December (in-feedlot weight) at $26 per cwt. Sale option weights for each animal included 1000 lbs. or 1050 lbs. with a sale price of $24 per cwt. at both options. Average daily gains for each animal during the feeding interval were 1.75 lbs. per day between 400 and 600 lbs., 2.25 lbs. per day between 600 and 700 lbs. and 2.75 lbs. per day between 700 and 1050 lbs. Maximum consumption of 90% d.m. feed was established as 2.25% of the animal's body weight.

Solution III included the same feeder cattle activity as solution II except the maximum consumption of 90% d.m. feed was increased to 2.50% of the animal's body weight. Comparison of solutions II and III shows the effects of increasing the feed consumption maximum of the animal.

Solution IV included steer calves purchased in December. The same prices, purchase weight and sale weight options described in solution II above were used. The average daily gains of the feeder animals were increased to 2.25 lbs. per day between 400 and 600 lbs., 2.75 lbs. per day between 600 and 700 lbs. and 3.25 lbs. per day between 700 and 1050 lbs. The maximum consumption of 90% d.m. feed for each animal was established at 2.50% of the animal's body weight. Results of solution IV show the effects of increased average daily gains over those used in solutions II and III.

Solution V included yearling steers purchased at 600 lbs. (in-feedlot weight) at $24 per cwt. Purchase options in both December and June were included. Sale prices and sale weight options for cattle were the same as those described in solution II. Average daily gains for the cattle were established at 2.25 lbs. per day between 600 and 700 lbs. and 2.75 lbs. per day between 700 and 1050 lbs. Maximum consumption of 90% d.m. feed for each animal was established at 2.50% of the animal's body weight. The results of solution V indicate the effects of including heavier yearling cattle in the farm organization and allowing a turnover of two groups of cattle in the feedlot during the operating year.

The stated objective of each of the individual solutions was the maximization of net farm income. In actuality, only variable costs were considered in the linear programming analyses and the value of the program obtained for each solution reflect total revenue less total variable costs. Annual costs associated with given resources for the farm, including depreciation, taxes and interest on investment, were calculated and deducted from the value of the program.

An opportunity cost of $1.50 per hour was charged against the operator's labor and deducted from the value of the program. The annual costs and operator's labor charge deducted were the same for all solutions. The residual amount remaining after these deductions will serve as the value for comparing solutions as a residual component of net farm income and is termed a return to management.

Linear programming analysis also gives insight into the value of limiting resources to the farm operation and the sacrifice in income forthcoming when production activities, not in the optimum farm plan, are forced to be included in the farm plan. The shadow price of a limiting resource indicates the value one more unit of resource would have to the farm operation. The shadow price indicates the marginal value product of the resource. An income penalty is associated with production activities not in the optimum plan. The income penalty of an activity indicates the reduction in the value of the program to be incurred if one unit of the activity were to be included in the final plan. Including one unit of the activity would force limiting resources from their optimum use and cause a reduction in the value of the program.

Table 13 shows the value of program, return to management, number of head of feeder cattle fed and operating capital used for solutions I-V. Activity levels, income penalties and shadow prices for plans I-V are shown in Appendix B.

Table 13. Value of program, return to management[a], number of cattle fed and operating capital requirements for solutions I-V

	I	II	III	IV	V
Value of program	$30,484.64	$34,676.75	$38,230.43	$38,285.05	$35,062.84
Return to management	8,127.14	12,319.25	15,872.93	15,927.55	12,705.34
Number of cattle fed	--	323.25	297.35	477.58	385.80 (Dec.) 116.84 (June)
Operating capital	14,980.50	66,717.66	60,915.80	77,174.13	56,179.47

[a]Annual costs of $18,180.00 for fixed resources and an operator's labor opportunity charge of $4,177.50 were deducted from the value of the program to obtain the return to management for all solutions.

The feed mix and quantities of feed fed to the feeder cattle enterprise in solutions II, III, IV and V are shown in Tables 14, 15, 16 and 17, respectively.

Solution I which included no feeder cattle gave a return to management of $8,127. Excess operator labor was available during all time periods. Land and the building limitations on farrowing sows were the limiting restraints in the solution. The shadow price for land (acre) in solution I was $59.77. Shadow prices for the winter-summer and spring-fall farrowing limitations were $190.70 and $182.92, respectively, for a sow with two litters. Operating capital used in solution I was $14,980 which was the lowest capital requirement of the five solutions.

Crop activities in solution I included 385 acres of continuous corn (spring plowing) with the sale of 32,000 bushels of corn.

Solution II showed a return to management of $12,319, approximately $4,200 greater than the return to management in solution I, and included 323 head of feeder cattle. The operating capital required in solution II was $66,717, a substantial increase over the capital requirement of $14,980 for solution I. Hired labor was purchased during the MAM and JJA periods with a shadow price of $3.82 per hour existent on the maximum hours of hired labor available.

Table 14. Solution II - Feed mix and quantities of feed fed to the feed cattle enterprise by period

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity[a]	Feed	Act. amount (tons) 90% d.m.	Total amount (tons) 90% d.m.	% total feed during period
DJF	90	323.25	400-560	P22 FA1	Corn silage	31.91		
				P22 FA2	" "	33.87	65.78	43.02
				P23 FA1	Grd. sh. corn	32.96		
				P23 FA2	" "	34.99	67.95	44.44
				P24 FA1	Grd. ear corn	6.18		
				P24 FA2	" "	6.57	12.75	8.34
				P30 FA1	SBOM	3.11		
				P30 FA2	"	3.30	6.41	4.20
							152.89	100.00
(48.5% of total feed fed for maintenance requirements during the period)								
(10.51 lbs. 90% d.m. feed/head/day 5.91 lbs. 90% d.m. feed/lb. gain)								
MAM	90	323.25	560-760	P22 FB1	Corn silage	22.42		
				P22 FB2	" "	30.96	53.38	25.50
				P23 FB1	Grd. sh. corn	45.43		
				P23 FB2	" "	62.74	108.17	51.68
				P24 FB1	Grd. ear corn	14.48		
				P24 FB2	" "	20.00	34.48	16.47
				P30 FB1	SBOM	5.57		
				P30 FB2	"	7.70	13.27	6.35
							209.30	100.00
(42.0% of total feed fed for maintenance requirements during the period)								
(14.40 lbs. 90% d.m. feed/head/day 6.47 lbs. 90% d.m. feed/lb. gain)								

[a]Feed activities are identified by six characters. The first four characters identify the feed. The fifth character identifies the feeding period. Character six distinguishes feed fcd for maintenance (1) and production (2), Tables 14-17.

Table 14. (Continued)

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
JJA	90	323.25	760-1000	P22 FC1	Corn silage	5.90		
				P22 FC2	" "	9.94	15.84	5.52
				P23 FC1	Grd. sh. corn	62.53		
				P23 FC2	" "	105.27	167.80	58.46
				P24 FC1	Grd. ear corn	28.80		
				P24 FC2	" "	48.48	77.28	26.92
				P30 FC1	SBOM	9.73		
				P30 FC2	"	16.38	26.11	9.10
							287.03	100.00
(37.25% of total feed fed for maintenance requirements during the period)								
(19.73 lbs. 90% d.m. feed/head/day 7.40 lbs. 90% d.m. feed/lb. gain)								
SON	50	323.25	1000-1050	P22 FD1	Corn silage	5.25		
				P22 FD2	" "	8.94	14.19	20.90
				P23 FD1	Grd. sh. corn	18.11		
				P23 FD2	" "	30.85	48.96	72.12
				P24 FD1	Grd. ear corn	.32		
				P24 FD2	" "	.54	.86	1.27
				P30 FD1	SBOM	1.43		
				P30 FD2	"	2.45	3.88	5.71
							67.89	100.00
(37.0% of total feed fed for maintenance requirements during the period)								
(21.00 lbs. 90% d.m. feed/head/day 8.40 lbs. 90% d.m. feed/lb. gain)								

Table 15. Solution III - Feed mix and quantities of feed fed to the feeder cattle enterprise by period

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
							90% d.m.	
DJF	90	297.35	400-560	P22 FA1	Corn silage	51.04		
				P22 FA2	" "	56.39	107.43	65.63
				P24 FA1	Grd. ear corn	18.55		
				P24 FA2	" "	20.50	39.05	23.85
				P25 FA1	Grd. corn cobs	8.18		
				P25 FA2	" "	9.04	17.22	10.52
							163.70	100.00

(47.5% of total feed fed for maintenance requirements during the period)
(12.25 lbs. 90% d.m. feed/head/day 6.89 lbs. 90% d.m. feed/lb. gain)

MAM	90	297.35	560-760	P22 FB1	Corn silage	34.70		
				P22 FB2	" "	48.94	83.64	38.77
				P24 FB1	Grd. ear corn	43.80		
				P24 FB2	" "	61.78	105.58	48.94
				P25 FB1	Grd. corn cobs	7.02		
				P25 FB2	" "	9.90	16.92	7.84
				P30 FB1	SBOM	3.98		
				P30 FB2	"	5.61	9.59	4.45
							215.73	100.00

(41.5% of total feed fed for maintenance requirements during the period)
(16.14 lbs. 90% d.m. feed/head/day 7.26 lbs. 90% d.m. feed/lb. gain)

Table 15. (Continued)

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
JJA	90	297.35	760-1000	P22 FC1	Corn silage	19.80		
				P22 FC2	" "	33.73	53.53	18.75
				P24 FC1	Grd. ear corn	77.11		
				P24 FC2	" "	131.36	208.47	73.03
				P25 FC1	Grd. corn cobs	.79		
				P25 FC2	" "	1.34	2.13	.74
				P30 FC1	SBOM	7.89		
				P30 FC2	"	13.45	21.34	7.48
							285.47	100.00
(37.0% of total feed fed for maintenance requirements during the period)								
(21.36 lbs. 90% d.m. feed/head/day				8.01 lbs. 90% d.m. feed/lb. gain)				
SON	50	297.35	1000-1050	P22 FD1	Corn silage	10.26		
				P22 FD2	" "	17.85	28.11	40.58
				P24 FD1	Grd. ear corn	14.28		
				P24 FD2	" "	24.83	39.11	56.46
				P30 FD1	SBOM	.75		
				P30 FD2	"	1.30	2.05	2.96
							69.27	100.00
(36.5% of total feed fed for maintenance requirements during the period)								
(23.32 lbs. 90% d.m. feed/head/day				9.33 lbs. 90% d.m. feed/lb. gain)				

Table 16. Solution IV - Feed mix and quantities of feed fed to the feed cattle enterprise by period

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
							90% d.m.	
DJF	90	477.58	400-600	P22 FA1	Corn silage	38.05		
				P22 FA2	" "	52.55	90.60	34.18
				P23 FA1	Grd. sh. corn	24.86		
				P23 FA2	" "	34.34	59.20	22.33
				P24 FA1	Grd. ear corn	42.93		
				P24 FA2	" "	59.29	102.22	38.56
				P30 FA1	SBOM	5.48		
				P30 FA2	"	7.57	13.05	4.92
							265.07	100.00
(42.0% of total feed fed for maintenance requirements during the period)								
(12.36 lbs. 90% d.m. feed/head/day 5.56 lbs. 90% d.m. feed/lb. gain)								
MAM	55	477.58	600-875	P22 FB1	Corn silage	.33		
				P22 FB2	" "	.63	.96	.02
				P23 FB1	Grd. sh. corn	117.63		
				P23 FB2	" "	224.06	341.69	86.71
				P24 FB1	Grd. ear corn	5.52		
				P24 FB2	" "	10.52	16.04	4.07
				P30 FB1	SBOM	12.56		
				P30 FB2	"	23.93	36.49	9.20
							395.18	100.00
(34.5% of total feed fed for maintenance requirements during the period)								
18.41 lbs. 90% d.m. feed/head/day 6.03 lbs. 90% d.m. feed/lb. gain)								

Table 16. (Continued)

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
JJA	55	477.58	875-1050	P22 FC1	Corn silage	7.74		
				P22 FC2	" "	15.73	23.47	7.60
				P23 FC1	Grd. sh. corn	76.96		
				P23 FC2	" "	155.88	232.84	75.67
				P24 FC1	Grd. ear corn	9.84		
				P24 FC2	" "	20.00	29.84	9.69
				P30 FC1	SBOM	7.54		
				P30 FC2	"	15.32	22.86	7.40
							309.01	100.00

(33.0% of total feed fed for maintenance requirements during the period)
(23.53 lbs. 90% d.m. feed/head/day 7.40 lbs. 90% d.m. feed/lb. gain)

Table 17. Solution V - Feed mix and quantities of feed fed to the feeder cattle enterprise by period

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
							90% d.m.	
Dec. purchased yearling steers								
DJF	90	385.80	600-825	P22 FA1	Corn silage	34.82		
				P22 FA2	" "	54.50	89.34	29.14
				P23 FA1	Grd. sh. corn	1.12		
				P23 FA2	" "	1.76	2.88	.92
				P24 FA1	Grd. ear corn	76.72		
				P24 FA2	" "	120.06	196.78	64.11
				P30 FA1	SBOM	6.99		
				P30 FA2	"	10.93	17.92	5.83
							306.92	100.00

(39.0% of total feed fed for maintenance requirements during the period)
(17.68 lbs. 90% d.m. feed/head/day 7.07 lbs. 90% d.m. feed/lb. gain)

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
MAM	82	385.80	825-1050	P22 FB1	Corn silage	43.37		
				P22 FB2	" "	73.88	117.25	31.72
				P24 FB1	Grd. ear corn	86.98		
				P24 FB2	" "	148.17	235.15	63.63
				P30 FB1	SBOM	6.36		
				P30 FB2	"	10.84	17.20	4.65
							369.60	100.00

(37.0% of total feed fed for maintenance requirements during the period)
(23.37 lbs. 90% d.m. feed/head/day 6.98 lbs. 90% d.m. feed/lb. gain)

Table 17. (Continued)

Feeding period	Days on feed	No. of head	Weight interval (lbs.)	Feed activity	Feed	Act. amount (tons)	Total amount (tons)	% total feed during period
June purchased yearlings steers								
JJA	90	116.84	600-825	P22 FCY1	Corn silage	10.55		
				P22 FCY2	" "	16.50	27.05	29.10
				P23 FCY1	Grd. sh. corn	.34		
				P23 FCY2	" "	.53	.87	.94
				P24 FCY1	Grd. ear corn	23.24		
				P24 FCY2	" "	36.36	59.60	64.12
				P30 FCY1	SBOM	2.12		
				P30 FCY2	"	3.31	5.43	5.84
							92.95	100.00
(39.0% of total feed fed for maintenance requirements during the period)								
(17.68 lbs. 90% d.m. feed/head/day 7.07 lbs. 90% d.m. feed/lb. gain)								
SON	82	116.84	825-1050	P22 FDY1	Corn silage	13.13		
				P22 FDY2	" "	22.37	35.50	31.72
				P24 FDY1	Grd. ear corn	26.34		
				P24 FDY2	" "	44.87	71.21	63.63
				P30 FDY1	SBOM	1.92		
				P30 FDY2	"	3.28	5.20	4.65
							111.91	100.00
(37.0% of total feed fed for maintenance requirements during the period)								
(23.37 lbs. 90% d.m. feed/head/day 6.98 lbs. 90% d.m. feed/lb. gain)								

Crops grown in solution II included 276 acres of corn and 109 acres of soybeans. As labor became limiting, a redistribution of crop production occurred to soybeans whose labor requirement per acre is less than that of corn. The shadow price on land was $32.45 per acre.

The shadow prices on the winter-summer and spring-fall farrowing restraints were $101.69 and $75.23, respectively. However, when feeder cattle were included in the farm organization, the shadow prices on limiting swine production facilities decreased substantially over those observed in solution I.

The 323 head of feeder cattle included in solution II were fed to 1050 lbs. An income penalty of $.83 per head existed for sale of cattle at 1000 lbs. The feed constituents in all four feeding periods include corn silage, ground shelled corn, ground ear corn and soybean oilmeal. During the first feeding period (DJF) corn silage and ground shelled corn formed 43% and 44%, respectively, of the total feed mix. Ground shelled corn constituted the largest percentage of the feed mix as the cattle became heavier. The percentage of the total feed fed required for maintenance of the animal declines as the animals become heavier.

The return to management obtained in solution III was $15,873 with $60,915 of operating capital required. This is a management return of approximately $3,500 greater than that obtained in solution II. Operator's labor was limiting during the MAM, JJA and SON periods with a shadow price of \$7.59 per hour for all three periods. Hired labor was purchased during the MAM and JJA periods.

Crop activities included in solution III were 214 acres of corn (spring plowed), 13 acres of corn (fall plowed), 145 acres of soybeans (spring plowed) and 13 acres of soybeans (fall plowed). Thus a notable shift to soybean production is seen as labor becomes limiting during the planting and harvesting seasons because of the reduced per acre labor requirement for soybeans over corn. Four hundred and thirty bushels of corn are purchased. A shadow price of \$25.06 per acre for land was obtained.

The shadow price per sow-2L for the winter-summer and spring-fall farrowing limitations were \$76.48 and \$44.22 respectively.

Two hundred and ninety-seven head of cattle were fed in solution III and all were fed to a finished weight of 1050 lbs. An income penalty of \$.76 per head was shown for cattle sold at 1000 lbs. While 25 head less cattle were fed in solution III as compared with solution II, a return to management approximately \$3,500 greater than that in solution II was observed. Cattle feeds utilized during the feeding periods included corn silage, ground ear corn, ground corn cobs and soybean oilmeal. As the cattle became heavier the percentage of corn silage fed decreased and was replaced by an increase in the percentage of ground ear corn in the feed mix for the feeding periods. The corn silage capacity was a limiting restraint showing a shadow price of \$5.18 per 90% d.m. ton. Ground corn cobs comprised 10% and 8% of the total feed during the first two feeding periods respectively. The percentages of total feed required for maintenance by the animals deviated less than 1% from those in solution II for all periods.

A substantially higher return to management is obtained in solution III while fewer cattle are fed and labor is released for other alternatives. Thus, a shift to greater utilization of bulkier feeds, i.e. corn silage, ground ear corn, ground corn cobs, in solution III indicates that the feed cost of gain may be substantially lowered per animal if the physiological restraints on consumption permit the consumption of these bulkier feeds.

A notable deviation from standard feeding practices, heretofore unmentioned, exists in the percentage of corn silage in the total feed fed during the last feeding period in both solutions II and III. The percentage of corn silage increases from 15% to 20% over the percentage of corn silage included in the total feed fed during the previous period. The weight gain interval during this last feeding period is 50 lbs. compared with approximately 200 lbs. weight gain during the first three feeding periods. The feeding periods were defined for this study on the basis of days and not weight gain intervals. More research is required to investigate the feed mix and quantities obtained in linear programming analyses when a smaller weight gain interval is used for each feeding period as opposed to large weight gain intervals, assuming the same average daily gain for both feeding periods. The maximum amount of roughage feed that may be fed to an animal to attain a given finished grade, especially during the latter feeding periods prior to sale, requires more investigation than was given in this study. The maximum amount of roughage that could be included in the feed mix was arbitrarily set at 50% of the maximum 90% d.m. feed for all feeding periods in the study. The restraint was not limiting during any period in the solutions obtained. A relationship between roughage consumption and desired finished grade may require more attention be given the roughage maximum than was given in this study.

Solution IV showed a return to management of $15,927 with $77,174 of operating capital required. Operator's labor was limiting during all four periods and hired labor was purchased during periods DJF, MAM and JJA. A shadow price of $6.49 per hour was indicated for operator's labor in periods DJF, MAM and JJA with a $4.49 per hour shadow price for hired labor.

Crop activities in solution IV included 193 acres of corn and 192 acres of soybeans with the majority of the plowing completed in the SON period because no cattle were fed during that period. Corn purchased was 17,272 bushels. A shadow price of $27.82 per acre was indicated for land.

Shadow prices for the winter-summer and spring-fall farrowing restraints were $52.84 and $13.49 per sow-2L, respectively.

Four hundred and seventy-seven head of cattle were fed in solution IV. Corn silage and ground ear corn comprised 34% and 38% of the total feed fed, respectively, during the first feeding period. Succeeding feeding periods showed ground shelled corn to be the major component of the feed mix comprising 87% and 76% of the total feed fed during period MAM and JJA, respectively.

It can be observed by comparing solutions III and IV that no increase in management return are obtained even though 180 head more cattle are fed. Thus an increased average daily gain with the same feed consumption restraints results in no increase in the return to management for the same resources. This is so because of the relatively less bulky feeds, i.e. ground shelled corn, required in solution IV to achieve the higher average daily gains. Production per acre of 90% dry matter feed is less for the less bulky feeds and more megacalories of net energy can be harvested per acre from corn silage than shelled corn.

A comparison of solutions II and IV offers insight into the effect of different average daily gains under the assumption that cattle consume more when higher average daily gains are achieved. Ground ear corn and ground shelled corn are the major constituents of the feed mix in all feeding periods for both solutions, with corn silage being fed during the first feeding period. The return to management obtained in solution IV is $7,600 greater than that obtained in solution II. The operating capital required in solution IV is $62,000 greater than that required in solution II. The type of cattle fed in solution IV thus offer an opportunity to substantially increase the return to management obtained from the same resources, although it must be recognized that a considerable amount of shelled corn was purchased as feed for the cattle.

Given the same price levels and net energy efficiency levels used in this study, the farmer feeder should purchase cattle that will achieve a higher average daily gain only so long as these higher gains allow more cattle to be fed. The feed cost per head for cattle in solution III was lower than that of the cattle in solution IV. Thus, fewer cattle fed in solution III resulted in a return to management comparable to that attained in solution IV. It must be recognized that the lower labor requirement per animal in solution IV allowed more cattle to be fed with the same labor limitations used in solution III.

Solution V showed a return to management of $12,705 with an operating capital requirement of $56,179. Operator labor was limiting in all periods and hired labor was purchased for periods MAM, JJA and SON with a shadow price of $2.62 per hour indicated for hired labor.

Crop production included 284 acres of corn and 101 acres of soybeans, with all plowing completed in the spring. A shadow price of $36.52 per acre was indicated for land.

Shadow prices of $99.82 and $71.28 per sow-2L were indicated for the winter-summer and spring-fall farrowing limitations, respectively.

Three hundred and eighty-six head of December purchased yearlings and 117 head of June purchased yearlings were fed to 1050 lbs. An income penalty of $2.68 per head was indicated for sale of the cattle at 1000 lbs. Corn silage and ground ear corn constituted approximately 30% and 64%, respectively, of the total feed fed during each of the feeding periods for both groups of cattle.

The yearling cattle fed in solution V compare with the calves fed in solution III with regard to the average daily gain and consumption restrictions imposed. A two cent price margin was used for the calves in solution III and a zero price margin for the yearlings in solution V. While 25 more head of cattle were fed and approximately $21,000 less operating capital was required in solution V than solution III, the return to management obtained was approximately $3,200 less than that obtained in solution III. Recall also that the yearling cattle could be purchased in December and June to enable a turnover of two groups in the feedlot in solution V, an opportunity not available to the cattle enterprise considered in solution III. Thus, the price levels used in this study for yearling steers do not give a return to management comparable with that obtained with steer calves having the same average daily gain and consumption and competing for the same resources. The return to management attributable to the first 200 lbs. of weight gain by the calves in solution III thus overshadows the return to management attributable to the increased number of yearlings fed in solution V.

Solution IV gave the largest return to management and required the greatest amount of operating capital. Cattle facilities assumed existent on the farm were also most fully utilized by the type of cattle considered in solution IV. Thus, the annual fix cost per head is lowered, a consideration that is significant in the long run.

The 500 head capacity of the cattle facilities does not approach the optimum size of feedlot in the farm resource base for the prices and resource limitations assumed in solutions II, III and V.

Several solutions were obtained by excluding the feed consumption and roughage consumption restraints. Analysis of the results showed the cattle to be consuming 90% d.m. feed at approximately 3% of their body weight. Consumption at this percentage of the body weight is unrealistically high for all cattle. Thus, the consumption restraint for cattle is necessary for obtaining realistic answers via the method of analysis used in this study.

The inclusion of feeder cattle in the farm organization increase the return to management for all types of feeder cattle investigated and at the price levels used. Increasing the average daily gain and feed consumption capability of the feeder give an increase in the return to management as evidenced by comparing solutions II and IV. Corn silage and ground shelled corn were the major feed components for both solutions. No difference in the return to management was observed between solutions III and IV. Thus, no advantage was shown for cattle achieving a higher average daily gain when feed consumption for cattle does not change. More extensive utilization of corn silage, ground ear corn and ground corn cobs by the cattle in solution III lowered the feed cost of gain to such an extent that the same return to management was achieved by feeding 180 fewer head of cattle than in solution IV. At price levels used in solution V, farm resources were not deployed to the feeder cattle to command a return to management comparable to solutions III and IV.

SUMMARY AND CONCLUSIONS

This study was initiated to investigate the economic forces exerted by the feeder cattle enterprise on farm organization. Specific objectives of the study were to determine the competitiveness of feeder cattle, the feed mix to be fed the feeder cattle and the optimum size of the feeder cattle enterprise for a given farm resource base. Feeder cattle were investigated as an integral part of the farm organization and not as an independent enterprise. The context of the study was a hypothetical study farm in northwest Iowa with land, buildings and machinery as given resources for the farm. Decisions for the farm were short-run decisions involving only variable costs. The annual costs associated with the given resources were considered as fixed costs.

Linear programming was employed as the mathematical tool for analysis. Five farm plans or solutions were developed via linear programming analysis to ascertain the effects of excluding feeder cattle from the farm organization as opposed to including feeder cattle with different purchase weights, average daily gains and feed consumption capabilities. Price levels used in the study were held constant between solutions.

The number of cattle fed and the feed mix to be fed to cattle were variables in all solutions. The unique feature of this study was the incorporation of the net energy system into the linear programming analysis to determine the least cost-profit maximizing feed combination and amount of each feed to be fed to the feeder cattle. Crude protein constituted a third nutritional consideration. Maximum feed consumption and roughage consumption by the feeder cattle was also considered.

The farm plan excluding feeder cattle from the organization showed a return to management of over $4,000 less than when feeder cattle were included at levels less than 500 head. Returns to management between $12,000 and $16,000 were indicated when feeder cattle were included in the farm organization. Thus, at the price levels assumed in this study, feeder cattle constitute a competitive activity for farm resource use.

An increase in the average daily gains of .5 lb. increased the return to management by $3,500. However, the increase in the average daily gain had no effect on the return to management when compared to the lower average daily gains the same level of feed consumption by the cattle. The cattle with the lower average daily gain were able to effectively use a greater percentage of corn silage, ground ear corn, and ground corn cobs to lower the feed cost of gain. Increasing the average daily gain at the same feed consumption level required a greater percentage of gound shelled corn to be included in the feed mix.

Corn silage was effectively used by both calves and yearlings during the initial feeding period. The percentage of ground ear corn in the feed mix decreased and was replaced by ground shelled corn as the average daily gains of the cattle were increased.

The restriction on the maximum consumption of feed by the cattle was shown to be limiting in all cases. Restrictions of 2.25% and 2.50% of the live body weight of the animal were used to determine the maximum consumption of 90% d.m. feed. Exclusion of this consumption restriction showed consumption of feed by the cattle at 3% of their bodyweight - an unrealistically high percentage.

Feeding periods for this study were defined to be three month intervals with the cattle weight gain increment during the period dependent upon the initial weight of the cattle and average daily gain of the cattle during the period. Significant deviations from the feed mix for previous periods were shown as the weight gain increment for a period became smaller. More research is required to determine the effect on the feed mix solution by varing the weight gain increment for a feeding period at various weight levels. Because of the nature of the methodology of using the net energy system with linear programming analysis, more computation problems are encountered as the number of feeding periods increase.

Price changes were not investigated in this study. Purchase options during different times of the year were included for only yearling steers. The flexibility of the net energy system in constructing feeder cattle requirements offers researchers an opportunity to investigate a wide range of cattle weight and average daily gain characteristics, along with price changes and farm resource considerations. Feeder cattle were shown to be a competitive enterprise for farm resources under the assumptions of this study. Major feed components included corn silage, ground ear corn, and ground shelled corn. The optimum size of the feeder cattle enterprise is dependent upon the farm resource limitations and indualistic to each farm. Labor limitations imposed on the study farm prevented full utilization of the cattle feeding facilities in several solutions. For the resource limitations of the study farm, the cattle achieving the higher average daily gains and capable of consuming large amounts of feed each day were shown to utilize the cattle facilities to near capacity.

The feeder cattle enterprise on Iowa farms will likely, under the price levels considered in this study, remain a competitive enterprise for farm resources and offer a profitable means through which the farmer may market the corn grown on the farm.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the guidance of Dr. S. C. James during the preparation of this thesis.

Appreciation is extended to Mr. Ron Winterboer for his assistance in dealing with machine computational problems.

Special thanks go to my wife, Cathryn, whose faith, encouragement and understanding were essential to the completion of this thesis.

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APPENDIX A

Appendix Table 1. Production, variable costs and capital requirements for crop activities[a]

	Corn ear	Corn grain	Corn silage	Oats grain	Oats silage	Soybeans	Hay baled	Haylage	Sorghum silage
Production (per acre)	100 bu.	100 bu.	17.4T	80 bu.	8.4T	33 bu.	2.6T	2.6T	6.0T
				(dollars)					
Growing									
Seed	4.36	4.36	4.36	6.14	6.14	3.56	--	--	4.00
Fertilizer	21.38	21.38	21.38	1.49	1.49	.46	--	--	10.67
Chemicals	2.80	2.80	2.80	--	--	3.56	--	--	2.00
Tractor and machine operating costs	2.46	2.46	2.46	1.26	1.26	6.07	--	--	2.46
Total growing	31.00	31.00	31.00	8.89	8.89	13.65	--	--	19.13
Harvesting	3.06	8.08	5.69	5.86	5.57	5.00	2.54	7.33	5.69
Total variable cost	34.06	39.08	36.69	14.75	14.46	18.65	2.54	7.33	5.69
Capital	23.86	24.87	24.39	5.32	4.12	11.74	.51	1.47	14.54

[a]Source: Cost data adapted from Van Arsdall (31) for 4-row equipment.

Appendix Table 2. Labor requirements for growing and harvesting crops[a]

	Per acre								
	Corn[b] ear	Corn grain	Corn silage	Oats[c] grain	Oats silage	Soybeans	Hay baled	Haylage	Sorghum silage
Growing				(hours)					
DJF	.21	.21	.21	.32	.32	.23	--	--	.21
MAM	1.65	1.65	1.65	1.00	1.00	.83	--	--	1.65
JJA	1.33	1.33	1.33	--	--	1.59	--	--	1.33
SON	.53	.53	.53	.40	.40	.30	--	--	.53
Total growing labor	3.72	3.72	3.72	1.72	1.72	2.95	--	--	3.72
Harvesting				(hours)					
DJF	--	--	--	--	--	--	--	--	--
MAM	--	--	--	--	--	--	--	--	--
JJA	--	--	--	2.27	2.53	--	5.78	4.03	--
SON	2.05	1.93	4.16	--	--	1.44	--	--	4.16
Total harvesting labor	2.05	1.93	4.16	2.27	2.53	1.44	5.78	4.03	4.16
Total growing and harvesting				(hours)					
labor	5.77	5.65	7.88	3.99	4.25	4.39	5.78	4.03	7.88

[a]Source: Adapted from data by Suter (25) and Van Arsdall (31).

[b]Assumes fall plowing.

[c]Includes labor for establishing a cover crop following oats.

Appendix Table 3. Variable costs and labor requirements for processing, loading and distributing feeds[a]

	Per ton (90% d.m.)									
	Corn silage	Ground shell-ed corn	Ground ear corn	Ground corn cobs	Oat grain	Oat silage	Baled hay	Haylage	Sorghum silage	Soybean oil meal
Variable costs				(dollars)						
Processing	--	.68	.68	.68	--	--	--	--	--	--
Loading	.27	--	--	--	.07	.27	--	.18	.27	.07
Distribution	.57	.19	.19	.19	.19	.57	--	.38	.57	.19
Total variable costs	.84	.87	.87	.87	.26	.84	--	.56	.84	.26
Labor				(hours)						
Processing	--	.50	.50	.50	--	--	--	--	--	--
Loading	.60	--	--	--	.17	.60	--	.50	.60	.17
Distribution	.49	.16	.16	.16	.16	.49	1.19	.33	.49	.16
Total labor	1.09	.66	.66	.66	.33	1.09	1.19	.83	1.09	.33

[a]Source: Adapted from data by Knight and Bortfeld (13), Suter (24) and Van Arsdall (30).

Appendix Table 4. Net energy[a] and protein[b] content of various feeds

Feed	Dry matter %	NE_m megacalories/c.w.t.	NE_p megacalories/c.w.t.	Crude protein %
Ground shelled corn	89.0	94	55	8.9
Ground ear corn	86.0	85	50	7.4
Corn silage (10 lb. urea added/T)	30.0	25	13	4.3
Ground corn cobs	90.0	50	30	2.1
Oat silage	30.0	19	11	2.9
Hay	90.0	53	23	12.0
Sorghum silage	30.0	20	9	2.3
Haylage	60.0	34	15	9.0
Soybean oil meal	90.4	94	55	45.0

[a]Net energy values taken from University of California data (3).

[b]Protein values taken from Morrison (17) and NRC (18).

Appendix Table 5. Prices used in the study

	Unit	Price
<u>Grains</u>		
Corn, shelled (sale)	bu.	$ 1.00
Corn, shelled (purchase)	bu.	1.05
Soybeans (sale)	bu.	2.30
Oats (sale)	bu.	.70
<u>Roughages</u>		
Hay, baled (purchase)	ton	21.00
*Corn silage	ton	10.00
*Sorghum silage	ton	8.00
*Oat silage	ton	9.10
<u>Concentrate</u>		
Soybean oilmeal	ton	94.00
<u>Livestock</u>		
Market hogs	cwt.	16.00
Sow	cwt.	13.00
Steer calves	cwt.	26.00
Steer yearlings	cwt.	24.00
Finished cattle	cwt.	24.00

*No sale or purchase; value assumed to develop capital coefficients.

Appendix Table 6. Operating capital requirements for feed and livestock activities

	Value	Period I[a]	Capital
<u>Feed (90% d.m.)</u>	(dollars)	(year)	(dollars)
(ton)			
Corn silage	30.00	.625	18.75
Shelled corn	35.70	.625	22.31
Ear corn	28.58	.625	17.86
Hay	21.00	.625	13.12
Haylage	31.00	.625	19.38
Soybean oilmeal	75.00	.300	22.50
Oat silage	26.00	.625	16.25
Sorghum silage	24.00	.625	15.00
<u>Livestock (excludes feed)</u>			
(per head)			
Steer calf (low ADG)	--	.9	118.32
Steer calf (high ADG)	--	.7	92.03
Steer yearling (low ADG)	--	.45	78.10
Steer yearling (high ADG)	--	.35	60.75
Hogs (sow and two litter, including feed)		.50	144.86
		Period II[b]	Capital
Corn silage		.400	12.00
Shelled corn		.400	15.00
Ear corn		.400	11.43
Hay		.400	8.40
Haylage		.400	12.40
Soybean oilmeal		. 00	22.50
Oat silage		.400	10.40
Sorghum silage		.400	9.60

[a]December purchased calves and June purchased yearlings.

[b]December purchased yearlings.

Appendix Table 7. Production, resource requirement, and variable costs of swine activities

	Winter-summer farrow		Spring-fall farrow
Production		(dollars)	
Number hogs	13.2		13.2
Value hogs produced	456.33		456.33
Value of sow replaced	39.00		39.00
Total value production	$495.33		$495.33
Labor		(hours)	
DJF	6.05		7.70
MAM	4.13		5.63
JJA	6.71		6.07
SON	3.26		5.67
Total labor	20.15		25.07
Variable costs		(dollars)	
Feed costs (excl. corn)	128.42		138.08
Vet. and medical	15.00		15.00
Miscellaneous	8.50		8.50
Total variable cost	$151.92		$161.58
Corn requirement (bu.)	137.8		139.0
Capital	$144.86		$144.86

[a]Source: Adapted from data gathered by Trede (29).

Appendix Table 8. Purchase cost, non-feed costs and labor for feeder cattle enterprises

	Steer calves	Steer yearlings
	(Per head)	
Purchase weight (lbs.)	430	645
Purchase cost	$111.80	$154.80
Non-feed costs[a]	(dollars)	
Veterinary and medical	1.50	.75
Bedding cost	.76	.76
Spray, fuel	.30	.25
Taxes	1.20	1.60
Market purchase cost	4.32	5.31
Market sale cost	6.84	6.84
Miscellaneous	.25	.25
Total	15.17	15.76
Unallocated feed cost	4.50	3.00
Labor[b] (non-feeding labor)	(hours)	
(Total hours for the three-month period)		
DJF	.60	.60
MAM	.45	.15
JJA	.36	.36
SON	.36	.36

[a]Source: Adapted from data compiled by Van Arsdall (32) and McCoy and Wakefield (16).

[b]Labor does not include distribution of feed to cattle. Source: Adapted from Knight and Bortfeld (13) and Van Arsdall (30).

Appendix Table 9. Annual costs for land, building and machinery resources

	Investment	Annual cost[a]
Cattle facilities[b] (500 head)	(dollars)	
Feed storage	$ 20,223	
Shelter, buildings, lots	29,072	
Equipment	7,885	
Total	$ 57,180	$ 5,260
Swine facilities[c] (20 sow farrowing unit, 400 hog finishing unit)		
Feed storage	500	
Buildings:		
Farrow	9,925	
Finish	4,900	
Equipment	1,500	
Total	16,825	1,350
Machinery storage[d]	2,000	200
Machinery[e]	23,150	3,010
Land[f]	180,000	8,360
Total		18,180

[a]Annual costs include depreciation, taxes, insurance and interest on investment.

[b]Source: Data taken from Van Arsdall (32) and Hoglund.

[c]Source: Data adapted from Trede (29).

[d]Source: Data taken from James (12).

[e]Source: Ibid.

[f]Source: Ibid., 1965 tax mill levy for O'Brien County, Iowa; 4% interest on land investment.

APPENDIX B

Appendix Table 10. Crop activity levels in solutions I-V

Activity	Description	Unit	Activity level I	II	III	IV	V
P02	Cont. corn, spring plow	acre	385.00	166.88	68.43	--	182.33
P03	C-Sb, fall plow	2 acres	--	26.87	13.40	186.27	--
P04	C-Sb, spring plow	2 acres	--	82.18	144.91	6.23	101.33
P08	Ear corn harvest	acre	385.00	247.65	175.00	170.68	232.62
P10	Corn silage harvest	acre	--	28.29	51.72	21.82	51.04
P15	Shell corn	100 bu.	385.00	209.54	55.78	125.66	61.57
P16	Shell corn	bu.	31,998.13	--	--	--	--
P17	Purchase corn	bu.	--	--	431.00	17,272.45	--

Appendix Table 11. Income penalties[a] for activities not included in solutions I-V

Activity	Description	Unit	Income Penalty I	II	III	IV	V
P01	Cont. corn, fall plow	acre	.11	.05	.05	.41	.11
P02	Cont. corn, spring plow	acre	--	--	--	.35	--
P03	C-Sb, fall plow	2 acres	3.35	--	--	--	.11
P04	C-Sb, spring plow	2 acres	3.24	--	--	--	--
P05	C-O-M-M	4 acres	39.82	41.22	15.73	--	11.94
P06	C-O-M	3 acres	29.48	27.15	--	6.67	12.94
P07	Sorgh-C-O-M	4 acres	--	--	--	--	--
P20A	Purchase hay, DJF	ton	1.00	--	--	1.08	--
P20B	" " MAM	ton	1.00	7.86	10.26	1.08	1.54
P20C	" " JJA	ton	1.00	7.86	10.26	1.08	1.54
P20D	" " SON	ton	1.00	7.71	10.26	.93	1.54
P101	Labor hire, DJF	hr.	2.00	5.82	7.60	--	2.86
P102	" " MAM	hr.	2.00	--	--	--	--
P103	" " JJA	hr.	2.00	--	--	--	--
P104	" " SON	hr.	2.00	.11	.11	.11	--

[a]The income penalty indicates the reduction in the value of the optimal solution by requiring one unit of the activity to be included in the solution.

Appendix Table 12. Capital, labor and swine enterprise activity levels in solutions I-V

Activity	Description	Unit	I	II	III	IV	V
				Activity level			
PCAP	Capital	Dollar	14,980.50	66,717.66	60,915.80	77,174.13	56,119.47
P101	Hired labor, DJF	hr.	--	--	--	31.32	--
P102	" " MAM	hr.	--	174.25	154.14	109.02	302.25
P103	" " JJA	hr.	--	225.75	245.86	259.65	32.43
P104	" " SON	hr.	--	--	--	--	65.32
P94	Swine farrow, W-S	Sow-2L	20.00	hog enterprise activity levels			
P95	Sale of hogs, May	head	144.00				
P96	Sale of hogs, Nov.	head	124.00	the same for all solutions			
P97	Swine farrow, S-F		20.00				
P98	Sale of hogs, Feb.	head	144.00				
P99	Sale of hogs, Aug.	head	124.00				

Appendix Table 13. Resource use in solutions I-V

			Activity level				
Row	Description	Unit	I	II	III	IV	V
RO1	Land	acre	385.00	385.00	385.00	385.00	385.00
R13	Op. labor, DJF	hr.	355.85	679.30	691.83	825.00	825.00
R14	" " MAM	hr.	1,022.95	1,035.00	1,035.00	1,035.00	1,035.00
R15	" " JJA	hr.	767.65	875.00	875.00	875.00	875.00
R16	" " SON	hr.	979.40	1,050.00	1,050.00	1,050.00	1,050.00
RL1	Hired labor	hr.	--	400.00	400.00	400.00	400.00
SCD	Silage capacity	ton	--	164.10	300.00	126.54	296.04
FMAX1	Farrowing capacity	Sow-2L	20.00	20.00	20.00	20.00	20.00
FMAX2	" "	Sow-2L	20.00	20.00	20.00	20.00	20.00

Appendix Table 14. Shadow prices[a] for limiting resources in solutions I-V

RO1	Land	acre	59.77	32.45	25.06	27.82	36.52
R13	Op. labor, DJF	hr.	--	--	--	6.49	3.47
R14	" " MAM	hr.	--	5.82	7.59	6.49	4.62
R15	" " JJA	hr.	--	5.82	7.59	6.49	4.62
R16	" " SON	hr.	--	5.71	7.59	6.38	4.62
RL1	Hired labor	hr.	--	3.82	5.59	4.49	2.62
SCD	Silage capacity	ton	--	--	5.18	--	--
FMAX1	Farrowing capacity	Sow-2L	190.70	101.69	76.48	52.84	99.82
FMAX2	" "	Sow-2L	182.92	75.23	44.22	13.49	71.28

[a]The shadow price indicates the increase in the value of the solution that would occur if one additional unit of resource were available.

Appendix Table 15. Income penalties on feeds not fed to the feeder cattle enterprise[a]

Feed	Solution II	III	IV	V
	(dollars per ton 90% d.m.)			
Period DJF	(48.5%)	(47.5%)	(42.0%)	(39.0%)
Grd. ear corn		5.33		
Grd. corn cobs	26.55	--	23.65	22.20
Oat silage	40.45	48.27	40.32	35.56
Hay	43.30	9.15	48.72	44.38
Sorghum silage	43.49	10.27	27.06	33.59
Haylage	41.16	--	38.61	41.38
SBOM	--	40.07	--	--
Period MAM	(42.0%)	(41.5%)	(34.5%)	(37.0%)
Grd. ear corn	--	5.41	--	2.81
Grd. corn cobs	23.64	--	20.92	5.97
Oat silage	39.83	44.54	35.66	23.20
Hay	36.47	10.92	43.10	37.60
Sorghum silage	35.04	12.17	23.94	30.16
Haylage	26.72	--	34.15	31.64
Period JJA	(37.25%)	(37.0%)	(33.0%)	(39.0%)
Grd. ear corn	--	3.56	--	2.98
Grd. corn cobs	21.86	--	20.47	22.09
Oat silage	36.83	33.14	34.89	36.78
Hay	33.72	7.18	42.17	43.91
Sorghum silage	32.39	11.30	23.42	32.65
Haylage	24.71	--	33.42	39.83
Period SON	(37.0%)	(36.5%)	--	(37.0%)
Grd. ear corn	--	6.08	--	--
Grd. corn cobs	21.76	.22	--	4.93
Oat silage	36.60	41.15	--	22.96
Hay	33.61	7.24	--	37.20
Sorghum silage	32.31	11.30	--	29.64
Haylage	24.77	--	--	31.52

[a]The income penalty shown must be interpreted in respect to the percentage of one ton of feed that may be used for maintenance purposes. The percentage of the feed fed that may be used for maintenance purposes is shown in parentheses for each period.