Cost Economies in Cattle Feeding and Combinations for Maximization of Profit and Stability

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CONTENTS

SUMMARY

This study deals with the effect of different cattle-feeding methods and systems on costs per steer fed, profit maximization and stability of returns. The first part of the empirical analysis deals with four different **methods** of feeding a given type of steer. The four methods are:

Feeding Methods

Method I: A standard ration is fed, mainly by hand-labor methods. Baled legume hay is fed in bunks near storage. Capital investment per steer is at a minimum for this method, but labor inputs per steer are much greater than for the other methods.

Method II: The same ration is fed by using a tractor-drawn wagon unloaded with a hand scoop. Baled legume hay is fed in hay bunks near storage. Method II requires a tractor and a wagon already available on the farm.

Method III: This method requires, in addition to corn-silage storage and a surface-silo unloader, a tractor, self-unloading wagon and equipment for loading silage and grain onto the wagon. Method III uses a greater amount of capital and a greater investment than Method I or Method II. Accordingly, Method III has lower labor requirements per steer, but has cost disadvantages for small herds because of its greater overhead or fixed costs.

Method IV: This method, the most highly mechanized one, uses the same procedure of feeding hay and removing silage from the silo as Method III, but the silage and grain are mechanically augered into a feeder. Method IV has the highest capital requirements. Also, capital investment increases at a faster rate than under Method III as the herd's size grows.

Labor requirements for feeding operations (silage and grain handling) under Method IV are lower at large volumes than for any other method. With respect to cost economies for each of the four methods, there are no important advantages after fixed costs are spread over a volume of about 500 steers. For a labor price of $2.50 per hour or above, however, there are some important cost advantages of more highly mechanized systems on a large-scale volume, as compared with small operations based more on hand-labor methods. Some small-scale operators, of course, place a very low charge on labor used during winter months and, hence, find income greater, other considerations aside, if they use the less-mechanized methods. At high labor costs (e.g., $2.50 per hour), large herds have considerably lower total costs per steer under Method III and Method IV than under Method I and Method II. Hence, we expect larger and more specialized cattle-feeding operations to have increased economic advantage as labor prices continue to rise relative to capital prices.

Combinations of Systems

The second part of the empirical analysis deals with combinations of different cattle-feeding systems to maximize profits within the over-all organization and resource restraints of an individual farm. The 11 cattle-feeding systems included in this analysis are: Good-choice steer calves; medium-good steer calves; good-choice heifer calves; good-choice, long-fed, yearling steers; good-choice, short-fed, yearling steers, winter; medium, short-fed, yearling steers; good-choice short-fed, yearling steers, spring; good-choice, short-fed, yearling steers, fall; good-choice, long-fed, 2-year-old steers; good-choice, short-fed, 2-year-old steers; medium, short-fed, 2-year-old steers.

Optimum farm plans, developed for 320-acre farms in the Clarion-Webster soil area with particular resource restraints, show the profit-maximizing size and combination of cattle-feeding systems to be a function of the amount of capital available. In general, for the specified resource situations, the linear-programming solutions indicate that a combination of cattle-feeding systems results in higher over-all farm profits than does a specialized system based on a single type of cattle. The higher profits result from more continuous use of feedlot space and equipment and more effective use of fixed labor supplies. In addition to the benefits from combinations noted, the income-variance study summarized next indicates that a significant reduction in variation of returns can be obtained by combining cattle-feeding enterprises.

Combinations for Income Stability

The third part of the analysis examines the variability of income attached to each of 11 systems and estimates combinations of pairs of systems that will minimize variability of returns from cattle feeding.

Cattle-feeding enterprises differ in the amount of income variability arising from price changes. Generally, the degree of variability varies directly with the proportion of total resource costs represented by the feeder animals. Measures of variability of return computed for the 11 cattle-feeding systems over the period, 1940-1963, show the relative income variability to be greatest for 2-year-old steers and yearling steers fed for a short period. Relative income variability is lowest for medium to good-to-choice steer calves and good-to-choice yearlings fed for a short period in the spring. Equations used to compute proportions of cattle from different systems that minimize variance show that greatest reduction can be obtained for such pairs as good-to-choice yearlings fed a short period in the spring

and good-to-choice 2-year-olds short fed (or medium yearlings short fed and good-to-choice yearlings fed for a short period in the fall). The former combination also enters the optimum plan in the linear-programming study. Little reduction in variability of returns is brought about by combining both yearlings and calves of good-to-choice quality fed over approximately the same period. Reduction in income variability is attained more consistently when the pairs considered are of different qualities and are fed in different times of the year so that price changes do not move in the same direction. Several pairs of cattle-feeding systems have changes in income that are negatively correlated and especially bring stability to farm income as they are combined in pairs.

Results of the second and third parts of the study indicate that farmers with limited capital and specific resource restraints may make more efficient use of their resources and minimize income variance by combining two or more cattle-feeding systems, rather than specializing in a single system. Single systems specialized in large units have greatest advantage under high labor costs. Hence, trends in resource prices that increase the price of labor relative to capital could be expected to encourage large-scale, specialized and mechanized feeding operations.

Cost Economies in Cattle Feeding and Combinations For Maximization of Profit and Stability [1]

by Earl O. Heady and James R. Gibbons[2]

Economic growth is having many important impacts on the structure of farming. One of the greatest effects of national economic growth on farm structure comes through changes in the relative prices of resources.

At low stages of growth, as in the United States a century back or in underdeveloped countries now, the supply of capital is small relative to the supply of labor. Consequently, the price of capital is relatively high, and the price of labor is relatively low. This situation of resource price favors farming methods or technology resting mainly on labor. The advantages of large-scale production methods, as represented in per-unit of production, then are small; large farms and large-scale enterprises have little advantage over smaller units.

Under an advanced stage of economic development, as in the United States currently, the relative supplies and prices of capital and labor are reversed. The prices of these two resources then favor greater capital investment and the substitution of capital for labor. New technologies resting more on capital are then favored. New capital technologies are now feeding rapidly into American agriculture. Under technologies employing a large amount of capital, fixed costs ordinarily are large and are generally committed to a single enterprise, and per-unit costs of production tend to be lower for large volumes or farms as compared with operations on a smaller scale.

These effects of economic growth and resource prices have been spread widely over U.S. agriculture in the last 3 decades. The average size of farms has been growing rapidly, and a parallel reduction has taken place in the number of farms, the farm work force and the proportion of the national population in agriculture. Economic growth and its reflection through relative supplies and prices of capital and labor resources also have rather direct impacts on the degree of specialization in particular farm enterprises.

When labor technology prevails and little capital is used for each enterprise, the diversified farm with several small enterprises may compete almost equally with a more specialized farm with one or two large enterprises, supposing that natural and economic conditions relating to production possibilities and price ratios are the same. When labor represents the majority of total resource inputs and when total fixed costs relating to capital are small, costs are relatively constant for either large or small enterprises, and farmers operating with different volumes may be on a comparable cost basis. One farm with three or four small enterprises may be at no great disadvantage as compared with separate large farms producing each of the enterprises singly and on a specialized basis. With the advent of technology requiring large capital investments and giving rise to high fixed costs, this similarity tends to disappear.

In contrast to labor technologies, the farmer often cannot afford a set of specialized equipment for several enterprises operated on a small scale. Each small enterprise will have high fixed costs per unit of production and may be at an economic disadvantage with large enterprises on farms specializing in a single commodity. In the latter case, only one set of specialized capital is required, and its fixed costs can be spread over a greater output to give lower unit costs of production.

These tendencies are being expressed in the degree of specialization among numerous regions of the United States. The number of farms with dairy cows has decreased, but the number of cows per farm has increased rapidly over the last 20 years. Broiler production has become concentrated on fewer but much more highly specialized farms. The trend toward large-scale specialized units for cattle feeding has developed rapidly in the Southwest over the last 10 years. Highly mechanized and specialized cattle-feeding units also are becoming more common in the Corn Belt.

Hence, these important questions arise: To what extent are there important cost advantages in large-scale mechanized and specialized cattle-feeding operations? Are highly specialized cattle-feeding systems best suited to typical commercial farms operating within the framework of (a) numerous alternatives in crop and livestock enterprises in conformance with soil and natural conditions and (b) limited supplies of capital and other resources? Also, problems of risk and uncertainty arise in connection with larger and more specialized cattle enterprises.

OBJECTIVES

This study has been made to analyze certain of these questions related to the size and degree of specialization in cattle-feeding operations. It is an initial

[1] Project 1328, Iowa Agriculture and Home Economics Experiment Station; Center for Agricultural and Economic Development, cooperating.

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investigation dealing with some of the more elementary aspects of these problems and represents application of relatively simple techniques to measure and specify quantities relating to costs and profits associated with the degree of specialization and the volume of operations for cattle feeding. More specifically, the objectives of the study are:

1. To determine the nature and extent of cost economies associated with various feeding techniques or methods as investment and size of the cattle enterprise are extended.

2. To estimate cost functions indicating the size of feeding operations necessary to attain low unit-production costs for each of four major methods of feeding and to determine the size of feeding operations to allow attainment of most of the cost economies; i.e., at what size will further expansion in the cattle-feeding operation produce only insignificant per-unit cost reductions?

3. To determine whether a combination of systems (different ages, qualities, times of purchase of feeder cattle and lengths of feeding period) add more or less to net farm income than specialized systems on farms with several resource restraints.

4. To measure the "degree of risk and uncertainty" that prevails for different systems of cattle feeding in relation to price variability.

5. To determine the effect of alternative combinations of cattle-feeding systems on variability of income and to indicate some combinations of systems resulting in minimum variability of returns.

PROCEDURE

The remainder of this report is divided into three parts. The first part includes an analysis of total and unit costs in cattle feeding. Cost curves for different systems of feeding and size of herds are presented to illustrate the extent and nature of cost advantages for operations of different sizes. The second part includes an analysis of the profitability of cattle-feeding systems in the over-all organization of farms. The third part provides an analysis of variability of returns from different cattle-feeding systems and from different combinations of cattle-feeding systems.

Total and unit cost curves, computed by budgeting methods or equations, are determined for four methods of feeding representing (a) a high-labor method applicable to small herds, (b) slightly more mechanization for somewhat larger operations, (c) a moderately mechanized system and (d) a highly mechanized system of feeding. Each method requires a somewhat different ratio of capital to labor. All four feeding methods, however, use identical rations for the cattle fed. Inputs or costs for each method are divided into (1) labor, (2) investment other than cost of feed and feeders and (3) operating costs. Operating costs include certain depreciation items, repair, insurance, fencing, gas, oil and livestock expenses. Livestock expenses cover transportation, veterinary expense, death loss and purchasing costs. Cattle and feed costs are not included since they are constant per animal for all systems used and all scales of operation considered. The size of individual operations considered ranged up to 2,000 head of steers.

The cost functions and relationships presented in the next section of this report are synthesized from the various resource inputs required for cattle feeding under the different systems analyzed. Data on inputs are drawn from existing experiments and farm records and surveys.

In the presentation of cost data, labor inputs, investment and operating expenses are first presented separately to illustrate the rate at which each declines in quantity per steer as size of feeding operations is increased for different methods. These costs are then combined to illustrate total nonfeed cost curves per steer when labor is priced at either $1 or $2.50. Two wage levels are used to illustrate the effect of different labor costs on cost functions and the most profitable herd size.

The second part of the analysis provides estimates of the kinds of cattle enterprises consistent with net-income maximization for farms of given size and with different amounts of capital. It is based on linear-programming models that allow capital resources to vary. The most profitable size and combination of 11 different cattle-feeding systems are derived for a 320-acre farm in north-central Iowa. This size was used because it conforms to the modal farm in central Iowa with cattle feeding as a major enterprise.

The third part of the analysis, estimating the combination of cattle-feeding systems that minimizes income variance, is based on price data for the years 1940-1963 and constant-input data for the 11 cattle-feeding systems. Measures of variability of income, based on annual price data, are computed for each cattle-feeding method. The combination of steers, from different pairs of methods, that minimizes income variation then is indicated.

COST RELATIONSHIPS IN CATTLE FEEDING

Cost Specification

Cost relationships or functions are computed for four basic methods of feeding good-to-choice steer calves. Although Iowa farmers feed numerous grades, weights and ages of steers, this analysis is limited to good-to-choice steer calves purchased Nov. 1 at weights of approximately 450 lbs. To keep cost estimates manageable, only one weight and type of cattle is used in the analysis of this section. Emphasis in this section is on the relation of the size and method of cattle-feeding operations on the cost of operations per steer. The methods analyzed represent different labor-capital combinations and total capital investments. Cost functions per steer under these different methods of feeding would generally be the same for different weights, grades and classes of cattle.

All cost analyses are based on a standard ration specified in table 1. The price relationships used for different feed items and cattle, both as feeder stock and finished animals, are based on the period, 1937-1965, and are adjusted to a $1.20 price per bushel of corn. Prices for grain and silage include storage costs.

Building Costs

Silo costs for the different cattle-feeding methods are based on the data in table 2. We assume that silo capacities are used according to the type and size of cattle-feeding operations.

Livestock shelter costs, other than a windbreak, are not included in the analysis since shelter is considered the same for all four feeding methods. Experimental evidence for Iowa suggests no advantages from more elaborate buildings and shelter in the central part of the state. The facilities of the Experiment Station at Iowa State University include both inside and outside feedlots. There is no observable difference in gains between the two systems. Outside lots without concrete floors have lower gains in the spring when weather is wet and mud gets deep.[3] A Kansas study suggested farmer preference for open pens over covered pens; where both were available on the same farm, open pens were used more frequently than covered pens.[4]

The amount of concrete flooring needed in cattle feeding depends on the location of the feedlot and the soil type and slope. We assume concrete flooring for all cattle in this study. Since there is little research on optimum size of feedlots, costs of 40 square feet of concrete lot space per steer are used in this study, although as little as 30 square feet per steer is sometimes considered adequate.[5] Cost of concrete lots includes a capital investment of $6.60 per steer and annual depreciation and repair cost of 72 cents per steer.

Fencing costs include a windbreak along one side of the area and cable or other low-cost fencing around the rest of the lot. The capital investment is computed at $1.19 per foot, with a yearly depreciation and repair cost of 9.5 cents per foot. The footage of fence increases with the number of steers, but in a decreasing proportion. Where a fenceline feed bunk is used, the cost of the bunk is reduced by the value of fence it replaces. Feed storage buildings costs also include part of the cost of the windbreak.

Feed Bunks

Two feet of feeding space per steer, or 1 foot of feed bunk per steer, is used at (1) a capital investment of 44 cents per foot and a yearly operating cost of 7.2 cents per steer for feedlot bunks or (2) a capital investment of $1.67 and an annual depreciation and repair cost of 29 cents for fenceline bunks.[6] Hay bunks have a

[3] From data provided by personnel of the beef nutrition section of the Animal Science Department, Iowa State University.

[4] J. H. McCoy and R. H. Wuhrman. Some economic aspects of commercial cattle feeding in Kansas. Kansas Agr. Exp. Sta. Bul. 424. 1960.

[5] Ibid.

[6] The feed bunks considered are wooden bunks of traditional construction and low original cost but of relatively short life. The fenceline bunks are more expensive because an all-weather road must be installed around the feedlot, and the cost is included with the bunk cost.

Table 1. Feeding system and feed requirements for fattening good-to-choice steer calves in drylot.[a]

Dates	Number of days[a] on feed	Feed required per head: Daily gain[d]	Corn, ground shelled	Protein supplement[c]	Minerals	Legume hay	Silage weight
		lb.	bu.	lb.	lb.	lb.	lb.
		Wintering phase					
Nov.-March	150	1.3		225	15	525	4,500
		Full-fed phase					
April-Aug.	150	2.4[c]	45	150	15	592	...
Total	300		45	375	30	1,117	4,500

[a] Developed in cooperation with research and extension personnel from the Department of Animal Science, Iowa State University.
[b] Gain during the wintering phase is 195 pounds and, over the full-fed phase, is 355 pounds.
[c] Stilbestrol is included to increase gains by 10 percent from given feed.

Table 2. Estimated investment and annual expenses in owning and operating concrete-stave tower silos and unloaders of different sizes.[a]

Silo size[b]	Corn silage capacity	Investment[c]: Silo	Unloader	Annual expenses[d]: Total	per-ton
feet	tons	$	$	$	$
12 x 40........	110	1,520	1,100	335	3.04
16 x 40........	180	2,080	1,200	403	2.24
18 x 40........	230	2,530	1,250	453	1.97
18 x 50........	290	3,050	1,250	499	1.72
18 x 60........	365	3,570	1,250	551	1.51
20 x 40........	290	2,820	1,400	506	1.74
20 x 50........	390	3,370	1,400	556	1.42
20 x 60........	500	3,920	1,400	605	1.21
20 x 70........	610	4,470	1,400	654	1.07
24 x 50........	550	4,550	1,700	716	1.30
24 x 60........	730	5,250	1,700	779	1.07
26 x 60........	860	5,700	1,800	839	0.98
30 x 60........	1,120	7,300	2,200	1,053	0.94

[a] Adapted partly from: C. R. Hoglund. Economics of bunker and tower silos. Mich. Agr. Exp. Sta. Quar. Bul. 41 (2):10 (table 2). 1957; and other available data on silo costs. It indicates the annual storage cost and unloading cost per ton of silage for concrete-stave tower silos of different sizes.
[b] Numbers refer to diameter x height of tower.
[c] Silo investment includes material and labor for silo, chute, ladder and foundation for silo size indicated in column 1 and purchase cost of unloader of proper size for silo. These are based on farmer prices for silos and equipment.
[d] Includes 6 percent interest charge of 50 percent of silo investment, plus depreciation, repairs and insurance on silo, roof and unloader (6 percent of new cost of silo and roof and 15 percent of new cost of unloader). Silo is depreciated over 25 years, and silo unloader over 10 years.

capital investment of 45 cents per steer and an annual depreciation and repair cost of 7.2 cents per steer.

Water

No costs other than additional water tanks are necessary for small herds. As herds get larger, capacity must be added to the water system, and costs are designed to cover cost of additional equipment and capacity. As size of herd increases, however, the cost of maintaining water temperature above freezing diminishes. For herd sizes between 50 and 300 steers, an annual fixed cost of $19.80 was charged to water equipment to cover depreciation, maintenance, taxes, insurance, electricity, etc. Depreciation was based on a 10-year life for equipment. Annual fixed cost was increased to $27.80 for 400 to 800 steers. Beyond 800 steers, an annual fixed cost was increased to $49.00.

Feeding, Grinding and Mixing

The cost of grinding is computed from capital investments ranging from $71 for 40 steers to $302 for 200 steers, with the systems repeated for larger herds. The total annual costs vary from a fixed cost of $32.50 and a variable cost of 22 cents per steer to a fixed cost of $71.20 and a variable cost of 11 cents per steer, depending on the feeding method.[7]

Marketing Costs

Marketing costs are included as a cash cost, with the feeder-steer price based on Kansas City, and the finished-steer price based on Chicago. The cash marketing costs (including charge of order buyer and costs of freight, insurance, yardage, commission, etc.) are estimated at $11.80 per head in computing variable operating costs.

Labor Costs

Not all labor on the farm can be hired and released at will. The appropriate price of labor, considering other opportunities for its use, may be 50 cents per hour in December and $3.50 per hour in June. Hence, in the first part of this study, labor costs are initially introduced in hours of labor per steer. In a later section, wage rates of $1 and $2.50 per hour are used to derive total cost curves and to compare costs per steer under various volumes of operation.

Power Costs

Power costs include farm tractor and electric motor expense. Electricity is priced at 2.5 cents per horsepower hour to include the marginal cost of electric power on farms. Tractor costs of 60 cents per hour represent the marginal cost of operating a tractor when it is not fully used in other farm operations. However, this cost includes some repairs because winter operation increases wear.[8]

Equipment Costs

Equipment costs include depreciation, shelter, taxes, insurance, repairs, maintenance and other capital costs of ownership. Depreciation is based on the straight-line method, with a salvage value of 10 percent. Four items are considered in determining useful life: (1) obsolescence, (2) deterioration, (3) use and wear and (4) farmer's planning horizon. Life length for the analysis varies from 10 to 15 years, depending on the equipment.

Repair and maintenance were computed as 1 percent of the purchase price. Taxes and insurance also were computed as 1 percent of the purchase price, and 7 percent of investment is used for investment cost.

METHODS OF STEER FEEDING

The four methods of steer feeding considered for the cost analysis were selected as common methods of feeding cattle used by Iowa farmers for different scales of operation and show a progressive substitution of capital for hand labor. All methods require silage storage and a surface silo unloader consistent with scale of the system. The cost of silage storage for each method is added to the feeding cost rather than to other costs. In this section, we show the following quantities per steer in relation to the number of steers fed under the four methods: feeding costs (see definition following), labor input, labor costs at two wage rates, capital investment (other than steer cost) and interest cost (other than for steers). The **feeding cost** excludes feed and steer costs (since these are considered the same per animal for all systems and scales of operation), labor and interest on investment. The feeding cost, in other words, includes all fixed and variable costs relating to equipment and buildings for the different feeding methods

Method I

The standard ration is fed by using a hand-carried basket and scoop. Baled legume hay is fed in hay bunks near storage. Capital investment per steer is at a minimum for this method, but labor inputs per steer are greater than for the other methods for larger operations. The various cost, input and investment items for Method I are included in table 3.

Although this method is not very common in Iowa, it is used for comparison of a "high-labor" method against "high-capital" methods.

[7] When the volume of steer feeding increased, the farmers surveyed by Purdue workers (R. C. Suter and S. H. Washburn. Feeder cattle systems of management: dollar costs and returns. Preliminary manuscript. Unpublished data. Purdue Agr. Exp. Sta. Res. Proj. 951.) increased the capacity of the feed grinder, added labor-saving attachments, and allocated a larger percentage of the total cost of grinding equipment to the steer enterprise.

[8] If feeding volumes beyond 2,000 steers were considered, the steer-feeding enterprise would need to be charged a higher price because additional tractor power typically would be purchased.

Method II

The standard ration is fed for Method II by using a tractor-drawn wagon unloaded with a hand scoop. Baled legume hay is fed in hay bunks near storage. Method II requires a tractor and a wagon already available on the farm. A tractor power cost of 60 cents per hour is included for all sizes of operations, and the partial cost of a wagon is added for herds of 400 and over. Method II (table 4) is only slightly more mechanized and capital intensive than Method I (table 3). Method II has somewhat higher feeding costs for small herds, but about the same costs for large herds. Similarly, capital requirements for Method II are somewhat larger for small herds, but as capital is spread over a larger number of steers, the difference is unimportant. Although labor costs are higher per steer for small herds than with Method I (especially because of care and handling of somewhat more equipment), the added capital allows labor inputs and costs to be lower than for Method I with larger numbers of steers.

Method III

This method requires, in addition to corn-silage storage and a surface silo unloader, a tractor, self-unloading wagon and equipment for loading silage and grain onto the wagon. The cost of fenceline bunks is included for Method III; feeders who use self-unloading wagons generally use fenceline bunks because of the difficulty in moving a self-unloading wagon through the feedlot. Costs are based on the automatic loading by such means as silage dropped directly on the wagon from the silo spout, grain from overhead bins or automatic mixer and (or) auger and self-unloading wagons. Two large wagons are assumed sufficient for easy feeding of the maximum number of steers considered.

Method III uses a larger amount of capital investment per steer than Method I or Method II. Accordingly, Method III has lower labor requirements per steer. It has cost disadvantages for small herds because of its greater overhead or fixed costs. Our concern is whether the spreading of these higher total fixed costs over a large volume of steers results in sufficiently lower capital costs, along with lower labor costs, to make the method more economical for large operations. Feeding costs per steer are much higher for Method III (table 5) than for Method II for small herds, but decline to the same level for herds of 2,000. Labor, of course, is not included in feeding costs, and the total costs per steer (see later section) become more relevant in evaluation of the least-cost method for large feeding operations. In comparing the labor costs of tables 4 and 5, Method III has some cost advantages over Method II when a price must be attached to the labor

Table 3. Method I: Per-steer capital investment, interest cost, labor input, labor costs and feeding costs for different numbers of cattle (costs of feed excluded).

Number of steers	Capital investment per steer[a]	Interest cost per steer[b]	Labor input per steer	Labor costs per steer @ $1 per hr.	Labor costs per steer @ $2.50 per hr.	Feeding cost per steer[c]
	$	$	hr.	$	$	$
10	91.15	7.83	12.20	12.20	30.60	41.41
15	63.93	5.68	9.11	9.11	22.77	34.27
25	42.20	3.95	6.60	6.60	16.50	28.58
40	29.75	2.97	5.19	5.19	12.97	25.34
50	25.53	2.64	4.72	4.72	11.80	24.25
70	21.21	2.29	4.19	4.19	10.47	23.01
80	19.60	2.16	4.02	4.02	10.05	22.61
100	17.50	2.01	3.78	3.78	9.45	22.16
125	16.45	1.91	3.61	3.61	9.02	21.61
150	15.04	1.80	3.48	3.48	8.70	21.36
200	13.48	1.67	3.32	3.32	8.30	20.92
300	11.75	1.54	3.17	3.17	7.92	20.51
400	10.94	1.48	3.09	3.09	7.73	20.38
500	10.76	1.46	3.07	3.07	7.67	20.24
600	10.25	1.43	3.03	3.03	7.57	20.23
700	9.91	1.40	3.01	3.01	7.52	20.22
800	9.65	1.39	2.99	2.99	7.47	20.22
1,000	9.27	1.35	2.96	2.96	7.40	20.13
1,300	8.92	1.32	2.93	2.93	7.32	20.06
1,500	8.76	1.31	2.92	2.92	7.30	20.03
2,000	8.50	1.30	2.91	2.91	7.27	19.95

[a] The investments in feed, feeder calf and operating cost are not included since they are considered the same per steer, regardless of the method and scale of operations.
[b] Interest cost includes interest on capital investment and interest on operating costs.
[c] Feeding costs include all costs other than feeder calf, feed, labor and interest on investment. They include depreciation on equipment, repair, insurance, taxes, fencing, gas, oil and livestock expenses. Livestock expenses cover transportation, veterinary expense, death loss and purchasing costs. Annual fixed and variable costs are included in figuring feeding costs per steer.

Table 4. Method II: Per-steer capital investment, interest cost, labor input, labor costs and feeding costs for different numbers of cattle (costs of feed excluded).

Number of steers	Capital investment per steer[a]	Interest cost per steer[b]	Labor input per steer	Labor costs per steer @ $1 per hr.	Labor costs per steer @ $2.50 per hr.	Feeding cost per steer[c]
	$	$	hr.	$	$	$
10	91.15	7.97	18.58	18.58	46.45	45.38
15	63.93	5.76	13.10	13.10	32.75	36.67
25	42.20	4.00	8.72	8.72	21.80	30.12
40	29.75	3.00	6.35	6.35	15.87	26.27
50	25.53	2.67	5.52	5.52	13.80	25.06
70	21.21	2.33	4.58	4.58	11.45	24.27
80	19.60	2.20	4.25	4.25	10.62	23.80
100	17.50	2.04	3.82	3.82	9.55	23.13
125	16.45	1.94	3.51	3.51	8.77	22.66
150	15.04	1.83	3.24	3.24	8.10	22.29
200	13.48	1.71	3.00	3.00	7.50	21.89
300	11.75	1.57	2.72	2.72	6.81	21.38
400	11.12	1.52	2.55	2.55	6.38	21.12
500	10.90	1.50	2.51	2.51	6.28	21.02
600	10.37	1.46	2.49	2.49	6.22	20.89
700	10.13	1.43	2.45	2.45	6.12	20.69
800	9.84	1.40	2.41	2.41	6.02	20.41
1,000	9.43	1.37	2.37	2.37	5.92	20.30
1,300	9.04	1.34	2.33	2.33	5.82	20.27
1,500	8.86	1.33	2.31	2.31	5.78	20.27
2,000	8.57	1.31	2.27	2.27	5.68	20.17

[a] See table 3
[b] See table 3
[c] See table 3

Table 5. Method III: Per-steer capital investment, interest cost, labor input, labor costs and feeding costs for different numbers of cattle (costs of feed excluded).

Number of steers	Capital investment per steer[a]	Interest cost per steer[b]	Labor input per steer	Labor costs per steer @ $1 per hr.	Labor costs per steer @ $2.50 per hr.	Feeding cost per steer[c]
	$	$	hr.	$	$	$
10	155.60	12.89	17.90	17.90	44.80	57.26
15	103.18	9.16	12.20	12.20	30.50	45.40
25	70.04	6.13	7.79	7.79	19.47	35.07
40	48.10	4.40	5.26	5.26	13.15	29.51
50	41.14	3.85	4.40	4.40	11.00	27.63
70	33.32	3.22	3.44	3.44	8.60	25.48
80	30.63	3.01	3.14	3.14	7.85	24.82
100	27.01	2.73	2.72	2.72	6.80	23.86
125	24.52	2.53	2.40	2.40	6.00	23.18
150	22.60	2.37	2.16	2.16	5.40	22.70
200	19.93	2.17	1.89	1.89	4.72	22.05
300	17.17	1.95	1.61	1.61	4.02	21.40
400	16.42	1.89	1.47	1.47	3.67	21.16
500	15.83	1.85	1.42	1.42	3.55	21.00
600	15.04	1.78	1.36	1.36	3.40	20.87
700	14.81	1.77	1.32	1.32	3.30	20.74
800	14.36	1.73	1.29	1.29	3.22	20.64
1,000	13.72	1.68	1.24	1.24	3.10	20.49
1,300	13.12	1.63	1.20	1.20	3.00	20.36
1,500	12.86	1.61	1.18	1.18	2.95	20.43
2,000	12.41	1.58	1.15	1.15	2.87	20.30

[a] See table 3
[b] See table 3
[c] See table 3

used, as would generally be the case for large operations (but not necessarily for small herds where the operator does not have alternative uses of his labor on small farms and during slack seasons). Method III also has a higher capital investment per steer than Method II, a consideration that becomes important for farmers with limited funds and numerous alternatives for the use of scarce capital.

Method IV

This method uses the same procedure of feeding hay and removing silage from the silo as Method III, but the silage and grain are augered into a feeder mechanically. Thus, a completely mechanical system is devised for all feed except hay. The mechanical feeders consist of a drive unit with feed hopper and a conveying unit. The conveying unit is powered with an electric motor. It is necessary to meter grain as well as corn silage into the conveying units.

Method IV also has a high capital requirement per steer. Each feeder may be used for a maximum of about 200 head. Then, the complete system must be duplicated. In addition, cross augers must be added. Hence, feeding costs under Method IV (table 6) do not diminish as rapidly with volume as under Method III (table 5).

Labor requirement for feeding operations (silage and grain handling) under Method IV is lower at large volumes than for any other method. (On a small scale, unreasonable under farm conditions, the greater amount of equipment would add to labor requirements per steer.)

COST AND INPUT FUNCTIONS

The basic data for input and cost curves in relation to the number of cattle fed are included in tables 3-6. However, equations 1-24 serve as the functions from which the curves are actually plotted. The equations are for capital investment per steer (equations 1-4), interest cost per steer (equations 5-8), labor hours per steer (equations 9-12), feeding costs not including feed per steer (equations 13-16), and total other costs per steer with labor at \$1 per hour (equations 17-20) and with labor at \$2.50 per hour (equations 21-24). In the equations, x refers to number of steers for the i-th feeding method, I_i to capital investment per steer, R_i to interest cost per steer, L_i to hours of labor per steer, F_i to feeding costs per steer, T_i to total costs per steer with labor at \$1 per hour and T_i' to total costs per steer with labor at \$2.50 per hour.

Capital investment in dollars per steer

Method I $I_1 = 868x^{-1} + 8.53 - 0.00047x$ (1)

Method II $I_2 = 850x^{-1} + 8.69 - 0.00055x$ (2)

Method III $I_3 = 1428x^{-1} + 12.41 - 0.00070x$ (3)

Method IV $I_4 = 1147x^{-1} + 13.78 - 0.00053x$ (4)

Table 6. Method IV: Per-steer capital investment, interest cost, labor input, labor costs and feeding costs for different numbers of cattle (costs of feed excluded).

Number of steers	Capital investment per steer[a]	Interest cost per steer[b]	Labor input per steer	Labor costs per steer @ \$1 per hr.	Labor costs per steer @ \$2.50 per hr.	Feeding cost per steer[c]
	\$	\$	hr.	\$	\$	\$
10	........126.82	10.57	13.30	13.30	32.50	48.18
15	.... 89.26	7.62	9.24	9.24	23.10	39.01
25	.... 59.20	5.25	5.93	5.93	14.82	31.63
40	.... 42.07	3.90	4.07	4.07	10.18	27.50
50	.... 36.30	3.45	3.45	3.45	8.62	26.08
70	.... 30.20	2.97	2.74	2.74	6.85	24.47
80	.... 28.04	2.80	2.52	2.52	6.30	23.92
100	.... 25.16	2.57	2.21	2.21	5.52	23.22
125	.... 24.35	2.49	1.98	1.98	4.95	22.67
150	.... 22.49	2.35	1.81	1.81	4.52	22.39
200	.... 20.13	2.17	1.60	1.60	4.00	21.83
300	.... 17.88	2.00	1.39	1.39	3.48	21.39
400	.... 16.67	1.91	1.29	1.29	3.22	21.12
500	.... 16.33	1.88	1.23	1.23	3.08	21.08
600	.... 15.67	1.84	1.24	1.24	3.10	21.00
700	.... 15.95	1.83	1.21	1.21	3.02	20.91
800	.... 15.49	1.81	1.19	1.19	2.98	20.89
1,000	.... 14.86	1.77	1.15	1.15	2.88	20.89
1,300	.... 14.32	1.73	1.12	1.12	2.80	20.78
1,500	.... 14.05	1.71	1.11	1.11	2.78	20.84
2,000	.... 13.85	1.70	1.09	1.09	2.72	20.71

[a] See table 3
[b] See table 3
[c] See table 3

Interest cost in dollars per steer

Method I	$R_1 = 67.90x^{-1} + 1.29 - 0.000035x$	(5)
Method II	$R_2 = 68.97x^{-1} + 1.32 - 0.000045x$	(6)
Method III	$R_3 = 103.02x^{-1} + 1.57 - 0.000051x$	(7)
Method IV	$R_4 = 89.53x^{-1} + 1.68 - 0.000037x$	(8)

Labor hours per steer

Method I	$L_1 = 91.8 + 2.87x - 0.000008x^2$	(9)
Method II	$L_2 = 168.7 + 2.21x - 0.000018x^2$	(10)
Method III	$L_3 = 165.0 + 1.08x - 0.000007x^2$	(11)
Method IV	$L_4 = 118.0 + 1.03x - 0.000004x^2$	(12)

Feeding costs in dollars per steer

Method I	$F_1 = 204 + 19.92x - 0.000060x^2$	(13)
Method II	$F_2 = 270 + 20.21x - 0.000200x^2$	(14)
Method III	$F_3 = 373 + 20.16x - 0.000055x^2$	(15)
Method IV	$F_4 = 262 + 20.59x - 0.000014x^2$	(16)

Total nonfeed costs in dollars per steer with labor at $1 per hour

Method I	$T_1 = 363.70x^{-1} + 24.08 - 0.000103x$	(17)
Method II	$T_2 = 508.97x^{-1} + 23.74 - 0.000263x$	(18)
Method III	$T_3 = 641.02x^{-1} + 22.81 - 0.000112x$	(19)
Method IV	$T_4 = 469.53x^{-1} + 23.30 - 0.000027x$	(20)

Total nonfeed costs in dollars per steer with labor at $2.50 per hour

Method I	$T_1' = 501.40x^{-1} + 28.18 - 0.000115x$	(21)
Method II	$T_2' = 763.97x^{-1} + 27.06 - 0.000263x$	(22)
Method III	$T_3' = 888.52x^{-1} + 24.43 - 0.000123x$	(23)
Method IV	$T_4' = 646.53x^{-1} + 24.75 - 0.000033x$	(24)

The curves in figs. 1-5 best illustrate the relationship among inputs or costs per steer as volume of feeding operations or steer numbers are extended. Since the slopes of the curves become almost horizontal and their relative positions become evident at less than 2,000 steers (the upper limit on the herd sizes included in tables 3-6), the curves in the figures are restricted to a range up to 500 steers. (For the several individual components of inputs and costs, the curves "become quite flat" as the number of steers approaches 500.) Finally, all nonfeed costs per steer are summed in fig. 5 to compare the systems at two wage rates, up to a 500-steer volume. Beyond 500 steers, the curves (not shown) have little slope, and the costs for Method III and Method IV become highly similar. The higher wage rate would seem most appropriate for large-scale commercial operations where competent personnel must be hired.

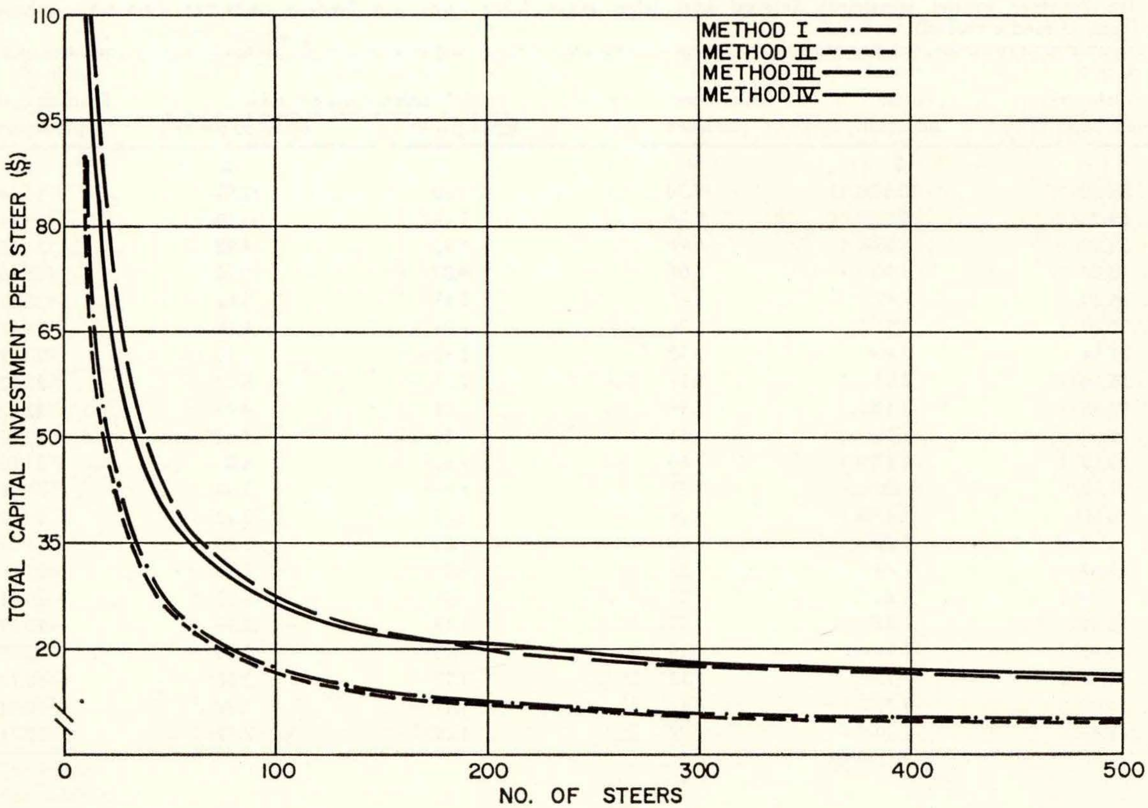

Fig. 1. Capital investment per steer for each of the four methods.

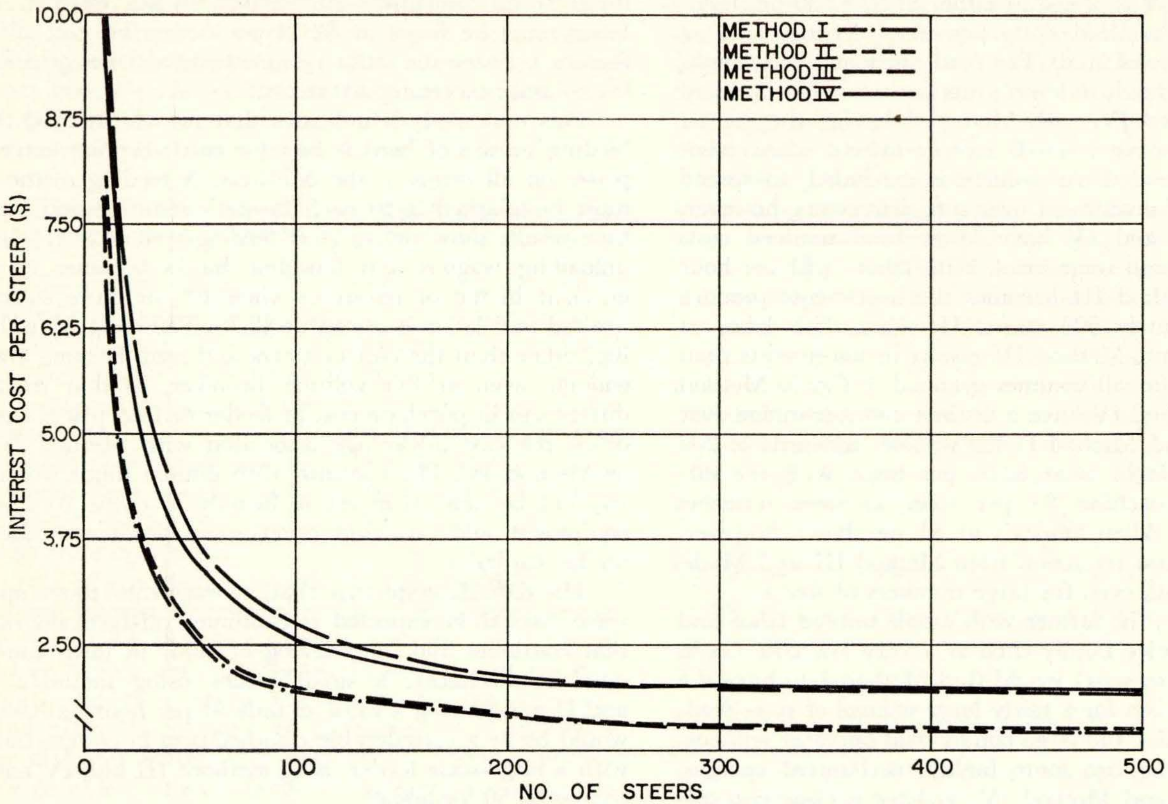

Fig. 2. Interest cost per steer for each of the four methods.

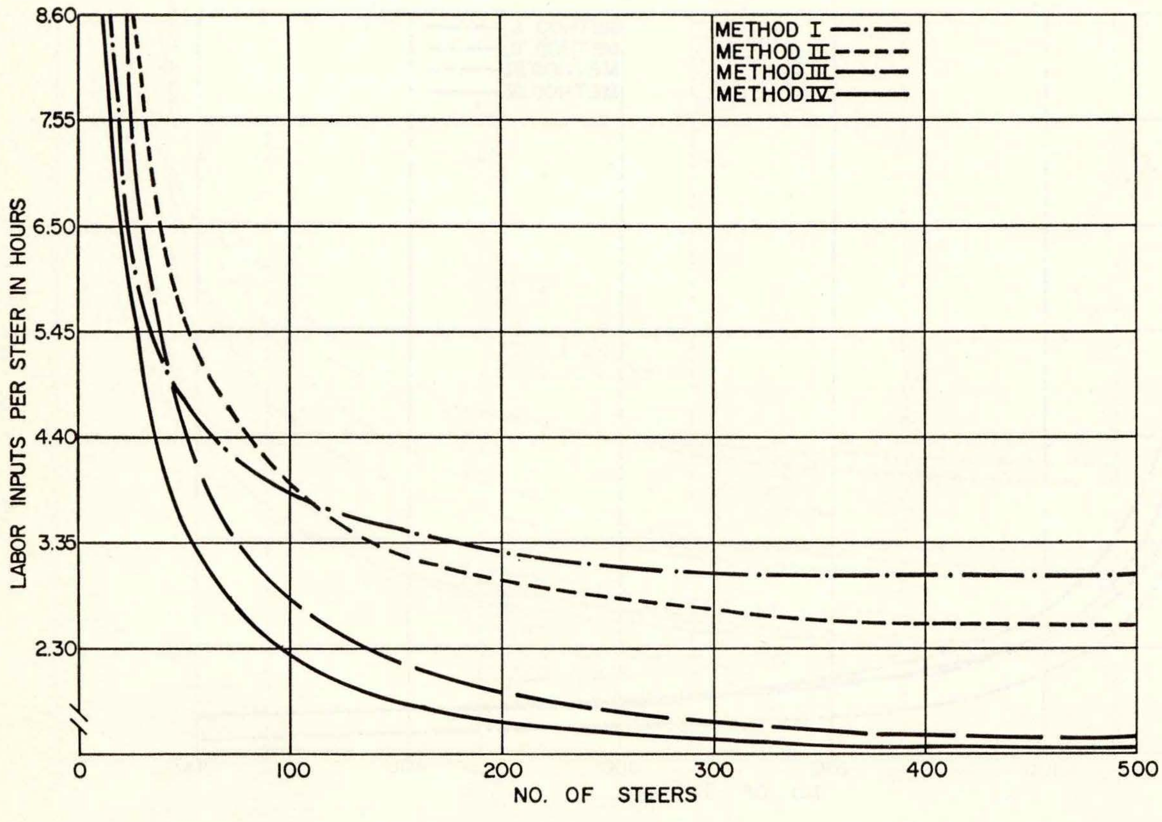

Fig. 3. Labor inputs per steer in hours for each of the four methods.

When labor is priced at either $1 or $2.50 per hour, fig. 5, total nonfeed costs per steer decline with an increase in size of herds. For small steer numbers, methods I and II result in lower costs per steer than Method III or Method IV, with Method I having the greater advantage for very small steer numbers when labor costs are included. As volume is expanded, to spread fixed costs of investment over sufficient steers, however, methods III and IV have lower total nonfeed costs per steer at both wage rates. With labor at $1 per hour (fig. 5), Method III becomes the lowest-cost practice at approximately 500 steers. However, with labor at $2.50 per hour, Method IV results in lower costs than Method III for all volumes graphed in fig. 5. Method III and Method IV have a distinct cost advantage over Method I and Method II for volumes upwards of 200 steers when labor is at $2.50 per hour, with the difference approaching $5 per steer as steer numbers exceed 500. When labor is at $1 per hour, however, the gain in cost reduction from Method III and Method IV is small, even for large numbers of steers.

Obviously, the farmer with ample unused labor and who might price family time at a very low cost (as in winter slack seasons) would find Method I to have the lowest cost, even for a fairly large volume of steer feeding. In contrast, the large commercial operator will certainly find the two more highly mechanized systems, Method III and Method IV, to have a clear cost advantage with large steer-feeding operations and labor hired from competing alternatives. When competent labor must be hired at $2.50 per hour, the cost difference between the latter two methods becomes greater for volumes exceeding 200 steers.

This cost analysis indicates that no one method of feeding or size of herd is best for cattle-feeding enterprises on all farms in the Midwest. A feeding method must be adapted to fit each farmer's resource position. Our results show that a steer-feeding system with self-unloading wagons and fenceline bunks becomes very efficient in use of resources when 100 or more steers are fed and labor is priced at $2.50. The costs of feeding, other than the cost of steers and feed, become low enough, even at this volume, however, so that small differences in purchase cost of feeder or feed prices can offset the cost advantage associated with Method III or Method IV. The operator with limited funds would (a) not be able to invest so heavily in cattle feeding equipment and (b) find other more productive uses for his capital.

The data do emphasize that, as wage rates move upward (as can be expected as continued off-farm migration continues and the backlog of labor in farm communities declines), a small feeder using methods I and II and placing a value of only $1 per hour on labor would be at a considerable disadvantage in comparison with a large-scale feeder using methods III and IV and paying $2.50 for labor.

These analyses are in terms of cattle feeding as a

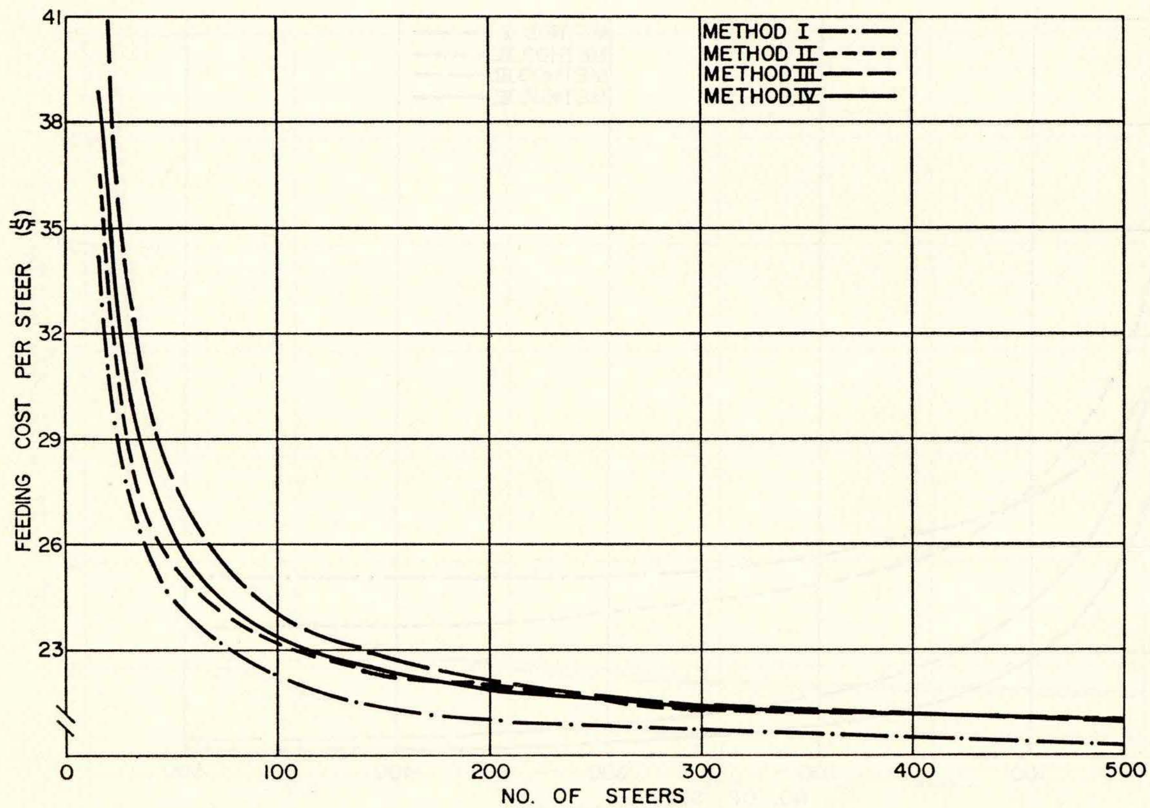

Fig. 4. Feeding costs (excluding feed and labor) per steer for each of the four methods.

single operation or specialized enterprise. The typical Iowa farmer tries to fit cattle feeding in with his over-all farming operations and hopes to maximize profits from his selection. Hence, we now turn to an analysis of different feeding systems as they relate to over-all farm organization on 320-acre farms in central Iowa.

CATTLE-FEEDING SYSTEMS IN RELATION TO THE MOST PROFITABLE ORGANIZATION OF FARMS

The previous section dealt with several alternative methods of feeding cattle. The methods examined required different amounts of investment in equipment and facilities for feeding a given age and grade of cattle. Interest was in per-steer costs of feeding operations in relation to the size of operations under the different methods. The results suggest that more intensive labor methods have lowest costs for small herds but that more intensive capital methods have a clear advantage for large-scale operations.

We now examine the selection of optimum cattle-feeding systems in relation to the over-all organization of farms. By **different systems,** we refer to different grades and classes of cattle fed under different arrangements (in contrast to the previous analysis, which dealt with the amount of investment and equipment for **different methods** of feeding for a given system). We consider scale economy possibilities in a somewhat more approximate method than in the previous section, by simply defining different activities over a range of each 50-head interval. Finally, for each optimum program computed, the farm organization was recomputed by using the costs for different methods presented in tables 3-6 for costs other than labor and feed when the programmed enterprises were of various sizes. In other words, for the number of animals obtained in the initial programming, costs for an enterprise of the same scale were taken from tables 3-6. The optimum program was then recomputed by using the latter costs. The resulting changes were only fractional, however, and the original programs and enterprise combinations are presented in the tables that follow. Even though integer programming might have been a preferable method of analysis, we use conventional programming models for the analysis. The analysis refers specifically to farms on Clarion-Webster soils, but the general results should be applicable for soils with similar yields and rotation possibilities.

Cattle-Feeding Systems

The cattle feeding systems included in the analysis are:

Good-choice steer calves: Good-to-choice steer calves weighing 450 pounds, purchased Nov. 1, are wintered on silage and hay. They are put on a full feed of grain and hay April 1 for approximately 150 days and are sold weighing 1,050 pounds in September.

Medium-good steer calves: Medium-to-good steer

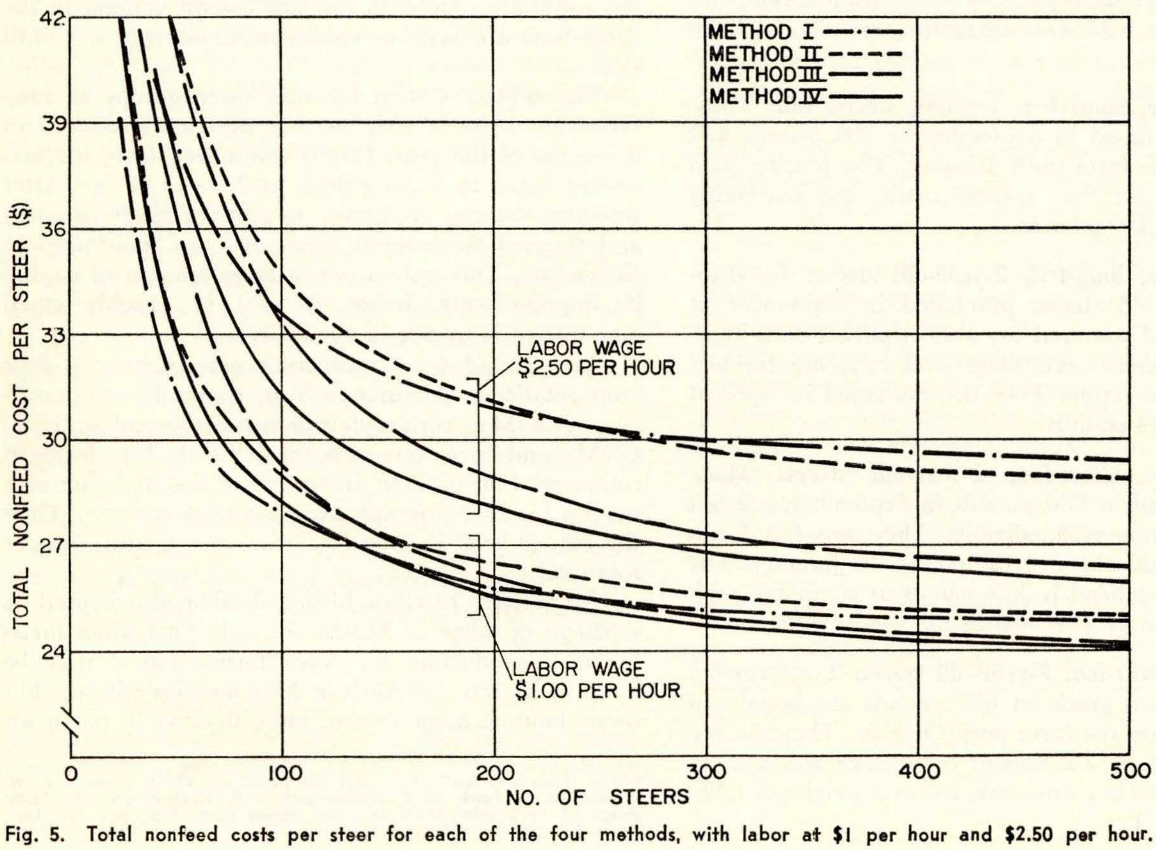

Fig. 5. Total nonfeed costs per steer for each of the four methods, with labor at $1 per hour and $2.50 per hour.

calves weighing 425 pounds purchased Sept. 1 are fed hay and silage for 180 days. They are put on a finishing ration of hay, silage, grain and supplement and sold about June 1 after a gain of 500 pounds. Less corn is fed to the medium-good steer calves than to the good-choice calves, and there are no cattle in the feedlot in July and August.

Good-choice heifer calves: Good-to-choice heifer calves weighing 425 pounds purchased Nov. 1 are full-fed hay, silage and some grain throughout the feeding period. Corn is increased in the last 90 days, and cattle are sold in June at a weight of 850 pounds.

Good-choice, long-fed, yearling steers: These steers are bought Nov. 1 at 650 pounds and kept on the farm until June. Feeding practices are the same as for choice calves except the wintering phase is shorter. The average gain per animal is 500 pounds.

Good-choice, short-fed, yearling steers, winter: Good-to-choice yearling steers, at 650 pounds, are purchased Nov. 1 and are put on full feed immediately. They are sold in late April or early May at 1,100 pounds.

Medium, short-fed, yearling steers: Medium yearlings are purchased in May at 650 pounds. They are put on a moderately high grain ration and are marketed in October at 1,050 pounds.

Good-choice, short-fed, yearling steers, spring: These steers are purchased Feb. 1 at 700 pounds and kept on the farm until June. A heavy grain ration with some silage is fed. The marketing weight is 1,100 pounds.

Good-choice, short-fed, yearling steers, fall: These steers are purchased in September at 700 pounds and are kept on the farm until January. The feeding plan is the same as for the "spring" cattle, and marketing weight also is 1,100 pounds.

Good-choice, long-fed, 2-year-old steers: Good-to-choice, 2-year-old steers, purchased in September at 800 pounds and wintered for a short period on a high-roughage ration of corn silage and hay, are finished on a high-grain ration. They are marketed in April at a weight of 1,214 pounds.

Good-choice, short-fed, 2-year-old steers: These cattle, purchased at 800 pounds in September, are put on a grain ration immediately. They are fed for a short period and sold at 1,180 pounds in January. The average gain per head is 380 pounds as compared with an average gain of 414 pounds for the long-fed cattle.

Medium, short-fed, 2-year-old steers: Two-year-old steers of medium grade at 800 pounds are bought in July and kept on the farm until October. They are fed 28 bushels of corn, 2.2 tons of corn silage and a small amount of hay. They are marketed at a weight of 1,120 pounds on Oct. 1.

Other enterprises and activities

Other enterprises and investment alternatives compete with cattle feeding for investment, feed, labor and other resources on the typical farm. Hence, it is necessary to define these activities for the analysis.

Four competing hog systems are used. These include a 1-litter system, a 2-litter system, a 4-litter system and a 6-litter system. They are allowed to compete for scarce resources, including building space for 60 litters.

For the 1-litter system, gilts are selected and bred to farrow in late May and are moved to pasture 2 weeks later. Pigs are weaned at 6 to 8 weeks, and all sows are sold after they are dry. Pigs are fed on pasture, allowed to glean corn fields and finished on drylot to be sold in December. Death loss after weaning is 1.5 percent.

For the 2-litter system, sows farrow in February through April and again in August through October. Pigs are weaned at 6 to 8 weeks of age. Spring pigs are moved to pasture for growing and finishing. Fall pigs are finished in drylot. Replacement gilts are kept as needed.

The 4-litter system includes two groups of sows farrowing twice yearly. Each group farrows in winter and summer, with 1 month between groups during each farrowing season. This farrowing system avoids heavy labor requirements for hogs during the busy spring and fall crop seasons. The litters and sows are moved from the farrowing house to the nursing-growing-finishing shed when the pigs are 2 weeks old. The pigs, as are the sows, are moved to the sow colony, remain in the sheds and are kept in confinement on concrete until sold.

The 6-litter system includes three groups of sows farrowing twice a year so that pigs are produced in 6 months of the year. Litters are moved from the farrowing house to nursing sheds at 2 weeks of age. After weaning, the pigs are moved to growing-fattening sheds and finished on concrete, and sows are transferred to the colony. This system uses a large amount of capital in improvements. Labor is used in roughly equal amounts each month of the year.

Also included as competing enterprises are four crop rotations: Continuous corn, corn-corn-oats-meadow (CCOM), corn-soybeans-corn-oats-meadow (CSb COM) and corn-corn-soybeans (CCSb). Two levels of commercial fertilization, intermediate and high, are considered for each rotation except continuous corn. Only the higher level is considered for corn grown without rotation.[9]

An activity to allow hiring of labor also is used. A shortage of labor in March through June often limits livestock production on Iowa farms. Labor may be hired in March and April or May and June if an additional hour of labor returns more than $1.10 per hour.

[9] Crop yields and fertilization rates are based on: W. D. Shrader, F. W. Schaller, J. T. Pesek, D. F. Slusher and F. F. Riecken. Estimated crop yields on Iowa soils. Iowa Agr. and Home Econ. Exp. Sta. and Iowa Coop. Ext. Serv. Spec. Rpt. 25. 1960.

Activities also are included in the programming model to allow sale of corn (corn-equivalent feed grains) for $1.20 a bushel and to allow corn to be converted to silage. Finally, an activity allows corn purchases at $1.30 per bushel.

Resource Supplies and Restrictions

The typical farm has limited resources that must be considered in specification of the most profitable combination of enterprises and practices. The resource restraints or supplies included for the 320-acre owner-operated farms considered in this study are explained below. The farms are composed of 300 acres of cropland, 11 acres of permanent pasture and 9 acres of roads, lots and waste. We make no differentiation of soil types of the typical Clarion-Webster soil grouping.

BUILDING AND EQUIPMENT RESTRICTIONS

A unit of hog space is that necessary for one sow and litter. Up to 60 sows and their corresponding litters are allowed in the programming analysis. Sufficient hay-and-grain storage space for all crops produced are included in the model. Feedlot capacity and feeding equipment for 500 head of feeder steers at any one time also are included. To allow for steer feeding enterprises that use the feedlot at different times of the year, feedlot restrictions are defined for five periods of the year: (1) September-October, (2) November-December-January, (3) February-March-April, (4) May-June and (5) July-August. For example, 500 steers can use the feedlot from November through January, and another 500 steers can use it during February through April. Although, we do not allow economies of scale in this system, we do allow for more intensive use of equipment and facilities by spreading the time of use over a longer period within any one year.

CAPITAL RESTRICTIONS

Plans are computed that by variable-resource programming that consider different supplies of operating capital.Operating capital includes funds that can be used on any of the enterprises or activities described previously. Certain of the lower capital levels may be representative of conditions for young farmers. Certain of the higher capital levels more nearly represent those of established and experienced operators not limited on funds.

Aside from harvesting machinery for corn and soybeans, sufficient farm machinery to crop each farm situation is assumed. Silage storage, silo unloader and a self-unloading wagon are considered available for cattle feeding.

LABOR RESTRICTIONS

Separate labor restrictions are used for the following monthly groupings: December-January-February, March-April, May-June, July-August and September-October-November. The fixed labor supplies in each period are summarized in table 7. In addition to family and operator labor, hourly labor can be hired for $1.10 per hour during March-April and (or) May-June for all enterprises. The fixed labor supply includes a full-time hired man, with the cost included in fixed costs.

Prices

Prices used represent "normal" or long-run price ratios among commodities, with the general level of prices adjusted to corn at $1.20 per bushel. The method used in adjusting prices is: The average price over the period 1937-1965 for each product is divided by the average corn price over the same period. This quotient is then multiplied by $1.20 to adjust all prices to a corn-price level of $1.20 per bushel.

Input Coefficients

The basic coefficients used (per animal for cattle and for the units indicated for hogs) for the programming analysis are included in table 8 for the several cattle and hog systems and in table 9 for the rotations. The coefficients selected for this analysis represent the level of management found on the better commercial family farms with fairly large cattle-feeding enterprises. We assume that farmers with large cattle-feeding enterprises have relatively more skill in beef production than in hog production.

Optimum Plans for 320-Acre Farms

The optimum or profit-maximizing plans, with capital at various levels, are presented in table 10. Column 2 of table 10 indicates the amount of operating capital required by the respective plans. Column 3 indicates the net income for each plan. Column 4 indicates the rotation and livestock enterprises optimum for the particular capital level. Column 6 indicates limiting resources. Column 7 indicates the amount of grain to be sold (plus) or purchased (minus), and column 8 shows the amount of purchased labor (beyond the "fixed" supply for operator and family and one hired man indicated in table 7).

When capital is very limited, enterprises giving the highest return per dollar invested are chosen first. Accordingly, a cash-crop rotation with the lower level of fertilization provides the optimum plan (plan 1) at the lowest capital level. Livestock are not produced because production and cash sale of crops give the highest returns on limited funds. Hence, the entire land

Table 7. Hours of labor available in the five periods, including family labor, a full-time hired man and the operator.

Period	Operator & family	Hired	Total
Dec.-Jan.-Feb.	624	624	1,248
March-April	552	332	884
May-June	520	520	1,040
July-Aug.	676	346	1,022
Sept.-Oct.-Nov.	663	663	1,326

area is planted to the $CCSb_1$ rotation. Land becomes limiting, and additional capital is then used to add fertilizer to continuous corn (plan 2) on the entire area. Once funds are available for added investment, fertilization provides the highest returns on scarce capital. With $6,620 of operating capital, investment in fertilization is more profitable than investment in cattle or other livestock, even though labor, buildings, feedlot and equipment are available for hog production and steer feeding.

As the amount of capital is increased, additional resources then become limiting and affect the combination of cattle-feeding systems and other enterprises that maximize profit. Farmers with large capital supplies thus must choose plans quite different from those chosen by farmers with similar physical resources but more limited funds. When capital is increased to $9,520, hogs produced under a 1-litter system are included in the optimum organization (plan 3). However, feeder cattle are not yet included. The 1-litter system has an advantage over the 2-litter system because corn gleaned from fields allows lower feed costs.

At capital levels of $10,970 and greater, 2-litter hog systems use the available hog shelter. Some hay production then becomes necessary because feeder cattle

Table 9. Labor requirements, operating costs and physical output per acre of selected cropping activities.

Item	$CCOM_1$[a]	$CCOM_2$[a]	$CSbCOM_1$[a]	$CSbCOM_2$[a]	$CCSb_1$[a]	$CCSb_2$[a]	Continuous $corn_2$[a]
Labor (hr.)	4.1	4.1	4.2	4.2	6.3	6.3	7.1
Operating cost ($)[b]	11.9	14.9	11.5	14.1	14.9	19.2	22.0
Feed grain produced (bu.)	39.6	44.4	31.9	35.1	40.8	46.7	72.0
Hay produced (ton)	0.8	0.9	0.6	0.7	0.0	0.0	0.0

[a] Subscript 1 refers to the intermediate fertilization rate. Subscript 2 refers to the high rate of fertilization.

[b] Operating costs include funds required for production, but not fixed costs.

Table 8. Basic resource requirements for the cattle and hog systems.

Activity	Labor: Dec.-Jan.-Feb.	Labor: March-April	Labor: May-June	Labor: July-Aug.	Labor: Sept.-Oct.-Nov.	Feed: Corn	Feed: Hay	Feed: Silage	Feed: Pasture
	hr.	hr.	hr.	hr.	hr.	bu.	ton	ton	day
Steer calves, good-choice	2.89	1.60	1.75	1.46	1.81	50	0.49	2.25	..
Steer calves, medium-good	2.89	1.58	1.74	..	2.29	25	0.49	4.00	..
Heifer calves, good-choice	2.89	1.58	1.74	..	1.06	35	0.40	2.00	..
Yearlings, good-choice, long-fed	2.97	1.93	1.74	..	1.06	55	0.40	2.50	..
Yearlings, good-choice, short-fed, winter	2.89	1.55	..	..	1.06	45	0.30	1.00	..
Yearlings, medium short-fed	..		1.74	1.74	1.82	25	0.30	3.00	..
Yearlings, good-choice, short-fed, spring	0.93	1.58	1.74	..	..	45	0.20	0.75	..
Yearlings, good-choice, short-fed, fall	2.89	0.79	..	..	0.91	45	0.20	0.75	..
2-year-olds, good-choice, long-fed	2.89	1.55	..	..	1.56	45	..	2.30	..
2-year-olds, good-choice, short-fed	2.51	..	..	..	2.89	35	..	2.00	..
2-year olds, medium, short-fed	..	..	..	1.93	2.89	28	..	2.20	..
Hogs, 1-litter	4.35	3.02	3.72	3.32	4.68	113	..	..	37
Hogs, 2-litter	10.26	7.79	5.64	6.70	8.77	214	..	..	36
Hogs, 4-litter	22.19	11.87	12.64	12.33	18.54	424	..	..	..
Hogs, 6-litter	29.06	20.89	20.42	18.90	27.42	637	..	..	..

Table 10. Optimum farm plans under different quantities of operating capital.

Plan	Capital level ($)	Net income[a] ($)	Enterprise	Level[b]	Additional resources limiting[c]	Corn surplus or deficit[d] (bu.)	May-June labor hired (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	4,470	7,279	$CCSb_1$	300	Land	+12,248	0
2	6,620	9,341	Continuous corn	300		+21,630	0
3	9,520	11,399	Continuous corn Hogs, 1-litter	300 20	Hog shelter	+19,367	0
4	10,970	12,130	Continuous corn Hogs, 2-litter	300 30		+18,422	0
5	11,540	12,344	Continuous corn $CSbCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring	298 2 30 7	May-June labor	+18,029	0
6	34,000	20,814	Continuous corn $CSbCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring Yearlings, good-choice, short-fed, fall	222 79 30 66 200	Feedlot capacity Sept.-Jan.	+2,468	0
7	37,670	22,047	Continuous corn $CSbCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring Yearlings, good-choice, short-fed, fall	210 90 30 108 200	Feed grain	0	55
8	46,120	24,633	Continuous corn $CSbCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring Yearlings, good-choice short-fed, fall 2-year olds, good-choice, short-fed	252 48 30 153 10 189	Sept.-Nov. labor	0	191
9	47,040	24,867	Continuous corn $CCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring Yearlings, good-choice, short-fed, fall 2-year olds, good-choice, short-fed	257 43 30 164 20 180	Feedlot capacity Feb.-June	0	211
10	52,670	25,781	Continuous corn $CCOM_2$ Hogs, 2-litter Yearlings, good-choice, short-fed, spring Yearlings, good-choice, short-fed, fall 2-year-olds, good-choice, short-fed	250 50 30 200 15 185	Forage	−1,970	264

Table 10. Continued.

Plan	Capital level ($)	Net income[a] ($)	Enterprise	Level[b]	Additional resources limiting[c]	Corn surplus or deficit[d] (bu.)	May-June labor hired (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
11	53,680	25,838	Continuous corn	241	Corn for silage	–2,719	258
			$CSbCOM_2$	59			
			Hogs, 2-litter	30			
			Yearlings, good-choice, short-fed, spring	200			
			Yearlings, good-choice, short-fed, fall	2			
			2-year olds, good-choice, short-fed	198			
12	57,120	26,013	Continuous corn	236	(Return on capital below 5% and none borrowed)	–3,727	295
			$CSbCOM_2$	64			
			Hogs, 6-litter	30			
			Yearlings, good-choice, short-fed, spring	200			
			Yearlings, good-choice, short-fed, fall	18			
			2-year olds, good-choice, short-fed	182			

[a] Net income, with all variable costs plus fixed costs of $6,750 deducted from gross returns.

[b] Units are acres for crops, litters for hogs and head (number) for cattle.

[c] Shows additional resource limiting. Hence, for each plan, all resources mentioned previously also are limiting.

[d] A plus (+) sign indicates a grain sale; a minus (–) sign indicates a corn purchase.

become profitable. Feeder cattle can compete with other enterprises for scarce resources only if a forage rotation is substituted for some of the continuous corn specified in plans 1 through 4. At a capital level of $11,540, a small herd of good-to-choice short-fed yearlings, purchased in winter and marketed in June, enter the optimum farm plan and use up the remaining May-June labor (in the fixed labor supply specified in table 7). When capital is increased to $34,000 (plan 6), 77 additional acres of land are shifted to a $CSbCOM_2$ rotation to supply additional hay; the feeder-cattle program is expanded to 200 head of good-to-choice yearlings fed from September to January and 66 head of the same cattle are fed from January to June. Because of large labor availability in the period, feedlot space obviously limits the size of the enterprise in the first period. Feeding the two herds in different seasons results in greater profit than one herd fed for a longer period because of more effective use of the scarce labor supply. Use of the feedlot for the two herds can be accomplished with the fixed labor supply, and labor does not have to be hired, as for one herd fed over a longer period. As capital moves to a slightly higher level (plan 7) some additional land is shifted to a hay rotation, and more cattle are fed in the January-June periods. A small amount of additional hired labor in the May-June period also is required.

At high capital levels (plans 8 through 12) 2-year olds of good-to-choice grade are substituted for some of the younger cattle. More labor is hired, and some land also remains in a hay rotation. The cattle are grain fed longer, but the feedlot can still be used for yearlings in the spring. The longer feeding period and larger gain per steer allow all resources to be more fully used and increase profits accordingly.

March-April labor is not a limiting resource for any of the capital levels specified. However, May-June labor becomes a limiting resource as soon as capital is increased to $11,540. Even though a full-time hired man is included in the fixed labor supply of table 7, net income can be increased by hiring additional May-June labor.

The programming analysis, in contrast to the previous cost analysis, shows a meshing of cattle-feeding systems with other enterprises to maximize profits within the framework of limited resources on an individual farm. Shifts among cattle-feeding systems with increases in capital also cause some shift in other enterprises, such as the crops grown within a rotation. Typically, the 1-man or 2-man farm would follow such alterations in its combination of enterprises, as capital becomes more plentiful, rather than extend the feeding a given type of cattle to a very large scale. The optimum method and system or combination of methods and systems thus will differ according to the conditions of the individual farm. On the other hand, farmers interested in placing major emphasis on large-scale cattle feeding, with minor concern with other enterprises, will find, as illustrated in fig. 5, that important cost economies do exist as size of the feeding enterprise is extended and as capital investment is used to lessen per steer labor requirements.

In general, however, the findings of this section suggest that the typical commercial farmer, who feeds some cattle but is not interested in setting up a highly specialized cattle-feeding system because of competition with other enterprises adapted to Clarion-Webster soils, will not find highly specialized enterprises the most profitable. Depending on the amount of capital available, a cattle-feeding enterprise will generally be included in the farm organization. Cattle feeding is specified in table 10 for all optimum farm organizations except those with less than $11,540 of operating capital. In the other situations, cattle enterprises of different sizes are meshed with other enterprises to allow the most profitable use of the various limited resources or restraints. In no case is it profitable to turn entirely to a specialized large-scale cattle-feeding operation, with hogs eliminated entirely from the plan. If capital is extremely limited, specialization moves in the direction of a cash-grain farm organization. For large amounts of capital on a 320-acre farm, a combination of cattle and hogs is always most profitable. Even though specialized cattle feeding operations may be established, with cattle taken out of competition with other enterprises not considered in the farm organization, it appears that diversification of livestock production between hogs and cattle feeding will remain the most profitable system in typical farm situations such as those analyzed.

VARIANCE IN INCOME IN RELATION TO SELECTION AND COMBINATION OF FEEDING SYSTEMS

Cattle feeding generally is considered "one of the more risky" enterprises of importance on Iowa farms. Hence, neither cost economies nor combinations of cattle-feeding methods and systems to maximize profits in any one year become the single criterion upon which selection is made. Farmers with small amounts of capital, especially, and frequently even those whose financial position is secure, sometimes look for combinations that may avert large losses under bad price breaks or that may provide greatest stability in returns over time. In this sense, farmers are unlikely to extend scale of feeding under one method simply to attain the greatest cost economies available. Too, as they search for combinations that provide the greatest security, they seldom select more than two cattle-feeding systems for this purpose.

Accordingly, in this section, we examine the relative variability of income for cattle-feeding systems and estimate the combinations of systems, from alternative pairs of systems, that will minimize the variance of income from cattle feeding. Some relatively simple empirical approaches are used in making this analysis. Although empirical methods of greater formality, such as integer-and stochastic-programming models within the over-all framework of a farm with scarce resources, could be used, we again abstract from the farm setting to examine the problem as one of cattle feeding alone.

The analysis that follows is one entirely of variability in income as related to price fluctuations. There are many other sources of variability, such as in death losses, but these are of lesser concern since some are insurable and others can be "managed" or controlled by practices such as feeding and buying. Price variations, and income fluctuations that attach to them, are entirely out of the farmer's control, except in limited opportunities in buying and selling futures.

Several measures are used to compute the degree of variability associated with price fluctuations, including the variance and the coefficient of variation, computed in the conventional manner but referring to a "population" of prices over the period, 1940-1963.

Procedure and Analysis

As a basis for the analysis, **returns** above feed costs per steer for the 11 feeding systems discussed earlier have been computed for a 24-year period. The **return** above feed and steer costs is based on feeder-cattle prices, finished-cattle prices and feed prices for each year of the period. The physical input-output requirements are those discussed earlier and are used as constants in all years. The **return** of each year has been deflated by the wholesale price index, to remove variability due simply to inflation in the postwar period.

Data on variability of **returns** for the 11 cattle-feeding enterprises are presented in table 11. The mean

Table 11. Variability of dollar return per steer for various cattle feeding systems during 1940-1963.

Feeder enterprise	Mean return	Variance	Coefficient of Variation: Amount	Coefficient of Variation: Ranks (lowest to highest)
Steer calves, good-choice	$83.73	666	30.8	1
Steer calves, medium-good	64.24	455	33.2	3
Heifer calves, good-choice	54.75	447	38.6	6
Yearlings, good-choice, long-fed	75.42	734	35.9	4
Yearlings, good-choice short-fed, winter	66.13	760	41.7	7
Yearlings, medium, short-fed	50.99	359	37.1	5
Yearlings, good-choice, short-fed, spring	50.16	267	32.6	2
Yearlings, good-choice, short-fed, fall	41.64	639	60.7	11
2-year olds, good-choice, long-fed	51.83	589	46.8	9
2-year olds, good-choice, short-fed	48.58	729	55.6	10
2-year olds, medium, short-fed	59.54	617	41.7	8

return in column 2 is for one animal in the period, 1940-1963. The coefficient of variation, the square root of the variance divided by the mean return, in column 3 is greatest (60.7 percent of the mean return) for the good-to-choice yearlings fed a short period in the fall (row 8). Although the feeding period is short, these cattle have a small return per head, a relatively large part of which is from price margin. Relative variation is the smallest (30.8 percent of the mean return) for the good-to-choice steer calves, which must be fed for a relatively long time and which give a larger **return** per steer, made up mostly of feed margin. Heavy yearlings and 2-year olds fed for short periods have, in an absolute sense, the highest variability of returns. Their margin above feed costs is determined relatively more by buying and selling prices and relatively less from feeding operations, as compared with smaller and younger animals represented by calves.

Table 12 includes the correlation matrix for the 11 feeding systems. Fourteen of the 55 pairs of feeding systems have negative correlation coefficients, indicating that, on the average over time, **return** for one system has changed positively when **return** for another system has changed negatively. Examples of negative correlation coefficients are good-to-choice steer calves purchased in November and sold in September and good-to-choice yearlings purchased in February and sold in June (correlation coefficient –0.092, row 7, column 1). Another example is of the latter good-to-choice yearlings combined with good-to-choice 2-year olds fed from September to April (correlation coefficient –0.605, row 9, column 6). Obviously, stability of return might best be attained by combining such pairs of feeding systems in the organization of farms. However, it is not necessary for the correlation coefficient to be negative for a gain in stability to be attained through a combination of systems. A small positive coefficient is preferable to a large positive one for these purposes, and the net effect on return variability of combining pairs of systems thus depends on the absolute value of the correlation coefficient and the magnitude of the return variance for the several systems.

Given certain quantities of resources to allocate between feeding systems, we can use the data of tables 11 and 12 to compute the variance of return when systems are combined in different proportions. We also can specify the particular combination that minimizes the variance of return, as illustrated in the following steps:

By using σ_A^2 to represent the return variance for one system A, q the proportion of total resources allocated to system A, σ_B^2, the variance for the other system B, and 1-q, the proportion of resources allocated to system B, the total variance, σ_T^2, for any allocation of resource between enterprises A and B can be represented as:

$$\sigma_T^2 = q^2 \sigma_A^2 + (1\text{-}q)^2 \sigma_B^2 + 2\rho_{AB}\, q(1\text{-}q)\, \sigma_A \sigma_B \quad (25)$$

In other words, the income variance for the combined systems is equal to q^2 times σ_A^2 (i.e., the variance for enterprise A) plus $(1\text{-}q)^2$ times σ_B^2 (i.e., the variance for enterprise B), plus the covariance where the term, ρ_{AB}, is the correlation coefficient relating return between enterprises A and B, and σ_A and σ_B represent the standard deviations of returns for systems A and B, with all quantities referring to the 1940-1963 period.

Marginal variance, indicating the change in variability accompanying each unit change in the resource allocation, q and q–1, between systems A and B, can be computed as the derivative of total variance with respect to q as in equation 26.

$$\frac{d\sigma_T^2}{dq} = 2q\sigma_A^2 - 2(1-q)\sigma_B^2 + 2\rho_{AB}(1\text{-}2q)\sigma_A\sigma_B \quad (26)$$

By setting this derivative equal to zero, we can compute the value of q, the proportion of resources (i.e.,

Table 12. Correlation coefficients of returns for pairs of the 11 cattle-feeding systems.

Feeder enterprise	Calves: Steers, Good-choice	Calves: Steers, Medium-good	Calves: Heifers, Good-choice	Yearling steers: Good-choice, long fed	Yearling steers: Good-choice, short-fed, winter	Yearling steers: Medium, short-fed	Yearling steers: Good-choice, short-fed, spring	Yearling steers: Good-choice, short-fed, fall	2-year-old steers: Good-choice, long-fed	2-year-old steers: Good-choice, short-fed	2-year-old steers: Medium, short-fed
Steer calves, good-choice	1.0										
Steer calves, medium-good	0.480	1.0									
Heifer calves, good-choice	0.635	0.908	1.0								
Yearlings, good-choice, long-fed	0.915	0.316	0.501	1.0							
Yearlings, good-choice, short-fed, winter	0.008	0.545	0.565	–0.064	1.0						
Yearlings, medium, short-fed	0.222	0.021	–0.080	0.172	–0.403	1.0					
Yearlings, good-choice, short-fed, spring	–0.092	0.448	0.376	–0.217	0.439	–0.131	1.0				
Yearlings, good-choice, short-fed, fall	0.195	0.438	0.551	0.199	0.556	–0.546	0.064	1.0			
2-year olds, good-choice, long-fed	–0.200	0.416	0.434	–0.172	0.700	–0.605	0.573	0.602	1.0		
2-year olds, good-choice, short-fed	0.243	0.389	0.517	0.168	0.583	–0.582	–0.012	0.924	0.482	1.0	
2-year olds, medium, short-fed	0.385	0.447	0.528	0.264	0.453	–0.243	–0.063	0.783	0.307	0.841	1.0

cattle-feeding space as represented by the number of steers) that will minimize income variance as in equation 27.

$$q = \frac{\sigma_B^2 - \rho_{AB}\sigma_A\sigma_B}{\sigma_A^2 + \sigma_B^2 - 2\rho_{AB}\sigma_A\sigma_B} \quad (27)$$

This equation, defining the value of q or the proportion of resources allocated to system A that will minimize total return variance from the two systems in combination, might specify a combination where the variance is low, in an absolute sense, but is high relative to the level of return. Consequently, equation 28 has been derived to specify the value of q that minimizes the coefficient of variation (the variability of return relative to the magnitude of return)

$$q = \frac{I_A\sigma_B^2 - \rho_{AB}I_B\sigma_A\sigma_B}{I_B\sigma_A^2 + I_A\sigma_B^2 - \rho_{AB}(I_A + I_B)\sigma_A\sigma_B} \quad (28)$$

where I_A is the mean return of enterprise A and I_B is the mean return of enterprise B over the years included. The square root of equation 25 divided by the return of the combined system as shown in equation 29 is the coefficient of variation of the combination.

$$CV = \frac{(q^2\sigma_A^2 + (1\text{-}q)^2\sigma_B^2 + 2\rho_{AB}q(1\text{-}q)\,\sigma_A\sigma_B)^{1/2}}{qI_A + (1\text{-}q)\,I_B} \quad (29)$$

Inserting the mean variance (table 11) and the correlation coefficient for **returns** (table 12) of all possible pairs of the 11 cattle-feeding systems in equation 28, the particular combination (q and 1–q) for each pair that minimizes the variance of **return** was computed and is presented in columns 1 and 2, table 13. (The value of q refers to the first-mentioned system of each pair, the value of 1–q to the second-mentioned system of the pair.)

Columns 3 and 4, table 13, respectively, show the coefficient of variation for the first-mentioned system in each line and for the variance-minimizing combination of each pair. The reduction in the coefficient of variation for the combination, as a percentage of the coefficient of variation for the first-mentioned system, is presented in column 5. Some combinations will not reduce variation; hence, the combination shown is 100 percent for one system. For example, all resources should be allocated to steer calves in comparison with heifer calves (row 11); 2-year olds as compared with yearlings fed in the fall (now 51); and medium 2-year olds compared with good-to-choice 2-year olds (row 55). In some cases, a larger percentage of resources should be allocated to one system and a smaller percentage to another system. Some combinations with two-thirds or more of resources allocated to the first system include: good-to-choice steer calves and heifer calves of the same quality (row 2); steer calves and yearlings (row 7); steer calves and good-to-choice 2-

Table 13. Proportion of resources allocated between pairs of feeding systems that minimizes variance or return and auxiliary data.

Line	Combination of enterprises	Proportion of steers in each system: q[a]	1 – q[b]	Coefficient of variation for: first-mentioned system[c]	combination of systems[d]	Percentage reduction in coefficient of variation
		1	2	3	4	5
1.	Steer calves, good-choice / Steer calves, medium-good	0.51	0.50	30.8	27.4	11.0
2.	Steer calves, good-choice / Heifer calves, good-choice	0.71	0.29	30.8	30.1	2.2
3.	Steer calves, good-choice / Yearlings, good-choice, long-fed	1.00	0.00	30.8	30.8	0.0
4.	Steer calves, good-choice / Yearlings, good-choice, short-fed, winter	0.59	0.41	30.8	24.9	19.2
5.	Steer calves, good-choice / Yearlings, medium short-fed	0.50	0.50	30.8	26.1	15.2
6.	Steer calves, good-choice / Yearlings, good-choice, short-fed, spring	0.50	0.51	30.8	21.8	29.2
7.	Steer calves, good-choice / Yearlings, good-choice, short-fed, fall	0.74	0.26	30.8	29.4	4.5
8.	Steer calves, good-choice / 2-year olds, good-choice, long-fed	0.55	0.45	30.8	23.2	24.7
9.	Steer calves, good-choice / 2-year olds, good-choice, short-fed	0.75	0.25	30.8	29.3	4.9
10.	Steer calves, good-choice / 2-year olds, medium, short-fed	0.66	0.34	30.8	28.8	6.5
11.	Steer calves, medium-good / Heifer calves, good-choice	1.00	0.00	33.2	33.2	0.0
12.	Steer calves, medium-good / Yearlings, good-choice, long-fed	0.60	0.40	33.2	27.9	16.0
13.	Steer calves, medium-good / Yearlings, good-choice, short-fed, winter	0.74	0.26	33.2	31.8	4.2
14.	Steer calves, medium-good / Yearlings, medium, short-fed	0.50	0.50	33.2	25.0	24.7
15.	Steer calves, medium-good / Yearlings, good-choice, short-fed, spring	0.42	0.58	33.2	27.9	16.0

Table 13. (Continued)

Line	Combination of enterprises	Proportion of steers in each system q^a (1)	Proportion of steers in each system $1 - q^b$ (2)	Coefficient of variation for: first-mentioned system[c] (3)	Coefficient of variation for: combination of systems[d] (4)	Percentage reduction in coefficient of variation (5)
16.	Steer calves, medium-good; Yearlings, good-choice, short-fed, fall	0.89	0.11	33.2	32.9	0.9
17.	Steer calves, medium-good; 2-year-olds, good choice, long-fed	0.73	0.27	33.2	31.6	4.8
18.	Steer calves, medium-good; 2-year olds, good-choice, short-fed	0.83	0.17	33.2	32.4	2.4
19.	Steer calves, medium-good; 2-year olds, medium, short-fed	0.68	0.32	33.2	30.9	6.9
20.	Heifer calves, good-choice; Yearlings, good-choice, long-fed	0.50	0.50	38.6	32.2	14.0
21.	Heifer calves, good-choice; Yearlings, good-choice, short-fed, winter	0.63	0.37	38.6	35.4	8.3
22.	Heifer calves, good-choice; Yearlings, medium, short-fed	0.46	0.54	38.6	25.7	7.5
23.	Heifer calves, good-choice; Yearlings, good-choice, short-fed, spring	0.35	0.65	38.6	29.1	22.0
24.	Heifer calves, good-choice; Yearlings, good-choice, short-fed, fall	0.90	0.10	38.6	38.4	0.5
25.	Heifer calves, good-choice; 2-year olds, good-choice, long-fed	0.65	0.35	38.6	35.4	8.3
26.	Heifer calves, good-choice; 2-year olds, good-choice, short-fed	0.83	0.17	38.6	37.7	2.3
27.	Heifer calves, good-choice; 2-year olds, medium, short-fed	0.60	0.40	38.6	35.0	9.3
28.	Yearlings, good-choice, long-fed; Yearlings, good-choice, short-fed, winter	0.54	0.46	35.9	26.3	26.7
29.	Yearlings, good-choice, long-fed; Yearlings, medium, short-fed	0.42	0.58	35.9	27.9	22.3
30.	Yearlings, good-choice, long-fed; Yearlings, good-choice, short-fed, spring	0.51	0.49	35.9	22.8	36.5
31.	Yearlings, good-choice, long fed; Yearlings, good-choice, short-fed, fall	0.68	0.32	35.9	33.3	7.2
32.	Yearlings, good-choice, long-fed; 2-year olds, good-choice, long-fed	0.96	0.04	35.9	34.7	3.3
33.	Yearlings, good-choice, long-fed; 2-year olds, good-choice, short-fed	0.66	0.35	35.9	32.4	9.8
34.	Yearlings, good-choice, long-fed; 2-year olds, medium, short-fed	0.54	0.46	35.9	30.5	15.0
35.	Yearlings, good-choice, short-fed, winter; Yearlings, medium, short-fed	0.54	0.46	41.7	23.6	33.8
36.	Yearlings, good-choice, short-fed, winter; Yearlings, good-choice, short-fed, spring	0.24	0.76	41.7	30.4	26.4
37.	Yearlings, good-choice, short-fed, winter; Yearlings, good-choice, short-fed, fall	0.81	0.19	41.7	41.2	1.1
38.	Yearlings, good-choice, short-fed, winter; 2-year olds, good-choice, long-fed	0.64	0.36	41.7	40.3	3.4
39.	Yearlings, good-choice, short-fed, winter; 2-year olds, good-choice, short-fed	0.78	0.22	41.7	40.8	2.2
40.	Yearlings, good-choice, short-fed, winter; 2-year olds, medium, short-fed	0.48	0.53	41.7	35.5	14.9
41.	Yearlings, medium, short-fed; Yearlings, good-choice, short-fed, spring	0.44	0.56	37.1	22.8	38.5
42.	Yearlings, medium, short-fed; Yearlings, good-choice, short-fed, fall	0.61	0.39	37.1	21.8	41.2
43.	Yearlings, medium, short-fed; 2-year olds, good-choice, long-fed	0.58	0.43	37.1	18.3	50.7
44.	Yearlings, medium, short-fed; 2-year olds, good-choice, short-fed	0.61	0.39	37.1	20.3	45.3
45.	Yearlings, medium, short-fed; 2-year olds, medium, short-fed	0.59	0.42	37.1	24.1	35.0

Table 13. (Continued)

Line	Combination of enterprises	Proportion of steers in each system q[a] 1	1 – q[b] 2	Coefficient of variation for: first-mentioned system[c] 3	combination of systems[d] 4	Percentage reduction in coefficient of variation 5
46.	Yearlings, good-choice, short-fed, spring; Yearlings, good-choice, short-fed, fall	0.76	0.24	32.6	29.4	9.8
47.	Yearlings, good-choice, short-fed, spring; 2-year olds, good-choice, long-fed	0.88	0.12	32.6	32.2	1.2
48.	Yearlings, good-choice, short-fed, spring; 2-year olds, good-choice, short-fed	0.74	0.26	32.6	17.3	46.9
49.	Yearlings, good-choice, short-fed, spring; 2-year olds, medium, short-fed	0.65	0.35	32.6	24.8	20.9
50.	Yearlings, good-choice, short-fed, fall; 2-year olds, good-choice, long-fed	0.23	0.77	60.7	45.8	24.6
51.	Yearlings, good-choice, short-fed, fall; 2-year olds, good-choice, short-fed	0.00	1.00	60.7	55.6	8.4
52.	Yearlings, good-choice, short-fed, fall; 2-year olds, medium, short-fed	0.00	1.00	60.7	41.7	31.3
53.	2-year olds, good-choice, long-fed; 2-year olds, good-choice, short-fed	0.45	0.55	46.8	44.4	5.1
54.	2-year olds, good-choice, long-fed; 2-year olds, medium, short-fed	0.36	0.64	46.8	35.8	23.5
55.	2-year olds, good-choice, short-fed; 2-year olds, medium, short-fed	0.00	1.00	55.6	41.7	8.4

[a] Proportion of feeder space allocated to first-mentioned system of pair.

[b] Proportion of feeder space allocated to second-mentioned system of pair.

[c] Coefficient of variation of first-mentioned system of pair taken alone.

[d] Coefficient of variation for variance-minimizing combination of the pair as shown in columns 1 and 2.

year olds (row 9); steer calves and medium 2-year olds (row 10); medium-to-good steer calves and good-to-choice yearlings (row 16); heifer calves and short-fed yearlings steers (row 24); and good-to-choice yearlings fed in the spring with those fed in the fall (row 46).

Reduction in Variation

The combination in row 48 has the smallest variation coefficient (17.3) given the data for the period mentioned. It is a combination of 73.6 percent good-to-choice yearling steers fed for a short period in the spring and 26.4 percent 2-year-old steers also fed a short period in the fall. Combining the two systems reduces the coefficient of variation by 46.9 percent, as compared with specialization alone in the yearling system. The combination, as compared with specialization, also causes only a very small reduction in return. The small negative correlation coefficient between the two systems is responsible for the large reduction in variation even though the second system, good-to-choice 2-year olds fed for a short time, has a high coefficent of variation.

The largest reduction in variation through combination is shown on row 43. It is accomplished through medium yearling steers (purchased in May and sold in October) combined with good-to-choice, 2-year-old steers (purchased in September and sold in April); both fed a short period, but at different times of the year. The relevant correlation coefficient (table 12), –0.605 for this pair, is the largest negative correlation of the matrix.

The 10 combinations with the lowest coefficients of variation (column 4) of table 13, with the coefficients of variation ranging from 17.3 to 24.1 (as compared with 30.8 for the most stable single combination of the 19) all have negative coefficients of correlation among income movements (table 12). Reduction in the coefficient of variation (column 5, table 13) through combinations is greatest for the following pairs: good-to-choice steer calves and short-fed good-to-choice yearlings (row 6); good-to-choice steer calves and long-fed 2-year olds (row 8); medium calves and short-fed medium yearlings (row 14); heifer calves and good-to-choice spring-fed yearling steers (row 23); good-to-choice yearlings long-fed and short-fed (row 28); good-to-choice yearlings and medium yearlings (row 29); long-fed good-to-choice yearlings and short-fed spring yearlings (row 30); good-to-choice yearlings and medium short-fed yearlings (row 35); good-to-choice yearlings winter fed and good-to-choice yearlings spring fed (row 36); medium yearlings and good-to-choice yearlings fed a short time (rows 41 and 42); medium yearlings and good-to-choice 2-year olds (rows 43, 44 and 45); good-to-choice yearlings and 2-year olds (rows 48, 49, 50 and 52); and 2-year olds fed for short and long periods (line 54). In all these reductions, comparison for the pair is with the coefficient of variation for the first-mentioned system by itself. In 19 combinations, the coefficient of variation is reduced by a fifth or more, in eight combinations by a third or more and in four combinations by two-fifths or more.

The highest coefficient of variation for any combination shown in table 13 (row 51) is for short-fed yearlings and short-fed 2-year olds, both of good-to-choice quality. The coefficient of correlation (0.924) is highly positive in table 12, and calculations show that variation cannot be reduced by combining the two systems. Hence, feeding all 2-year olds is preferable to a combination of the two systems if the criterion is maximum stability of returns.

The next largest variation for a combination is found on row 50 and includes good-to-choice, 2-year olds fed for a long period combined with the same yearlings as for row 51. The results show the combination to include 23.2 percent yearlings and 76.8 percent 2-year olds. The correlation coefficient (table 12) between the two is 0.602. The coefficient of variation for the pair is 45.8, a 24.5-percent reduction from the 60.7 of the yearlings alone. However, when the combination is compared with the 2-year olds, with a coefficient of variation 46.8, the reduction is only 1.0 percent.

The eight combinations with the highest variance are all combinations of short-fed yearlings and 2-year olds with medium or high positive correlations between the income changes for indicated years. In three cases where combinations do not reduce income variation, the pairs of cattle (a) are both purchased or sold at about the same time of the year and (b) have returns that come mainly from price margins, rather than feed margins. In contrast, the 10 combinations with the smallest variance all have negative correlation coefficients between income changes and represent cattle fed at different times of the year.

The results of the analysis show that, given our data, a significant reduction in variance can be accomplished by combining cattle systems that are purchased and sold at different times of the year and (or) that are of a different age and grade. A farmer who is risk conscious or not able to absorb losses in particular years can find two kinds of cattle-feeding systems that lead toward this goal, but still fit into the farm organization with respect to utilization of forage, off-season labor and other limited resources.

Some relatively large reductions in return variance are possible through selection of cattle-feeding systems that use both the resources and facilities at different times of the year and have a negative or relatively small positive correlation in income change. Thus, some farmers will continue to combine two cattle systems fed out separately at different times of the year and meshed with other farm enterprises and (as suggested in the first part of this study) not extend given systems and methods to a large-scale basis. This condition best applies to young farmers or others with limited capital who may be nearly as concerned with the stability and certainty of income as with the level of return. Hence, the cost economies associated with larger herds of a given system may have little more effect on decisions than the prospects of large risks from feeding on a large volume. In the case of large-scale commercial operators, where cattle feeding is the dominant or single enterprise, the cost economies associated with large volumes may more nearly draw decisions toward single systems and methods. These farmers also, however, may be interested, especially because of the high capital and risks involved, in combining systems that allow diversification in income changes and prospects but still allow attainment of the scale economies for specialized enterprises as analyzed in the first part of this study.

The wide range in market grades, age and time of feeding found in the low-variance combinations allow feeding of most kinds and grades of cattle to attain a combination that gives a relatively low income variance.