Potential Agricultural Production and Resource Use in Iowa

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PREFACE

This report summarizes cooperative research between Iowa State University and the U.S. Department of Agriculture. It is a contribution to a regional study, NC-54, of supply response and adjustments for hog and beef cattle production. The Iowa study included three parts: (a) a time-series analysis showing the role of the North Central Region in the United States feed-grain-livestock economy; (b) a linear-programming analysis, based on assumptions set forth by the NC-54 regional committee, of representative Iowa farms to provide normative supply functions for the state; and (c) a linear-programming analysis in which the conditions and assumptions of the second part of the over-all study were modified.

This report summarizes the work completed in the third part of the over-all study. The results for parts (a) and (b) were presented previously (5). Also. part (a) is reported in detail elsewhere (24).

The results from part (b) indicated that the model used needed to be changed to fully express the potential of Iowa agriculture. Part (c), therefore, included two objectives: first, to determine the production potential of Iowa agriculture if every Iowa farmer used the best farming techniques available and, second, to determine the production potential of Iowa agriculture if every Iowa farmer continued to use the techniques actually used during 1957-1961.

CONTENTS

SUMMARY

The purpose of this study is to estimate the production or supply potential of Iowa agriculture and is part of a regional study designed for this purpose. Two levels of efficiency are examined in the Iowa study, average technical efficiency and advanced technical efficiency. The pattern of output, resources used, and levels of farm income are analyzed under both conditions. This summary, however, refers only to the conditions of advanced technical efficiency.

A representative farm-aggregation model was used in a linear-programming analysis of resource allocation and potential production. Thirty-one Iowa farms (representative of all the commerical crop and livestock farms in Iowa) were described from primary and secondary data. Linear programming was used to obtain 40 optimal solutions under the advanced-technical-efficiency model for each the 31 representative farms. Each solution resulted from a unique set of sale prices for soybeans, hogs, and beef cattle. The soybean price was either $2 or $2.35 a bushel. The price of hogs ranged from $10.40 to $15 per hundredweight, and the price of choice beef cattle ranged from $16 to $24 per hundredweight. The sale price of corn was $1 a bushel for all 40 solutions. Relatively low livestock prices were used to obtain aggregate livestock supply functions over a relevant quantity range. At each of the 40 price combinations, the optimum solutions for the representative farms were aggregated to give 40 aggregate solutions for Iowa.

As expected, the optimum quantity of beef produced in Iowa increased as the price of beef increased. The same price-quantity relationship also held for pork production and soybean production. Over the 40 solutions, live beef production varied from 89 million pounds to 21 billion pounds, and live hog production varied from zero to 30 billion pounds. Soybean acreage varied, under the 40 price combinations, from 277,000 acres to 7 million acres, and corn acreage varied from 12 million to 17 million acres. In 1965, Iowa farmers raised 4.7 billion pounds of live beef, 4.45 billion pounds of live hogs, 4.8 million acres of soybeans, and 9.9 million acres of corn. They also diverted 3.5 million acres of potential corn land for payment under the 1965 Feed Grain Program.

The production figures lead to two conclusions. First, Iowa agriculture has a much greater production potential than is being realized. There are adequate quantities of capital and labor available to Iowa farmers to enable them to greatly expand hog production, beef production, or both. Second, the optimum, organization of agriculture in Iowa changes drastically with changes in product prices.

Our results show that, with the use of feasible agronomic practices, a maximum of 19 million acres of row crops (corn and soybeans) could be grown in Iowa. The acres of corn and soybeans raised was a function, not only of the corn-soybean price ratio, but also of the beef-hog price ratio. When the hog price was high relative to the beef price, corn production became relatively more profitable than soybean production. Soybean acreage could have been increased to about 9 million acres if (a) the soybean price had been increased to $3 a bushel, (b) the corn price had been held at $1 per bushel, and (c) the price of hogs was low relative to the price of beef.

The production potential of Iowa agriculture is indicated in two ways: One is the quantity of farm resources used in those solutions, with aggregate production levels near current production levels in Iowa. Comparisons can then be made between the actual resources used on Iowa farms and the minimum amount of resources needed to produce current levels of farm output. Of the 40 solutions, solution 27 had production levels nearest actual farm production in 1965: In solution 27, optimum production of beef cattle was one-third higher than actual beef cattle production in 1965, corn production was about 20 percent higher, soybean production was about 50 percent higher, and pork production was about the same as in 1965. For solution 27, 12 million man-hours of labor were hired, but 108 million man-hours of operator and family labor went unused. Labor was hired because of the uneven distribution of farm labor demands throughout the year. Capital was also abundant. For all farms as a whole, 933 million dollars of additional liquid assets were available on farms and could have been invested in the farm business. These funds were not distributed equally among the farms, however, because funds were borrowed on some of the representative farms. Solution 27 showed that a total of 11 million dollars was borrowed to help pay for operating expenses. In other words, only 66 percent of the operator and family labor and only 60 percent of the capital available for investment in the farm business were actually used in a solution where livestock and crop production were greater than in 1965.

Another way to show the production potential of Iowa agriculture is to examine those solutions in which most of the farm resources are used in the optimal production of farm products. Solution 28 shows Iowa's potential for beef-cattle production, and solution 37 shows Iowa's potential for hog production. Solution 28 was computed by using $24 cattle and $10.70 hogs. Optimally, there would be specialization in beef production on Iowa farms at these prices. A quantity of beef equivalent to nearly half of the nation's beef consumption in 1965 could be raised on Iowa farms if the assumptions used in solution 28 were met. Most of the capital and labor supply available to Iowa farmers were exhausted in farm production in solution 28.

For solution 37, $16 cattle and $15 hogs were used. In solution 37, hog production is 6.9 times that of 1965

in Iowa, or 1.7 times actual U.S. hog production in 1965. In contrast to solution 28, most of the Iowa farm resources are invested in hog production. Because of resource limitations, only a small increase in optimal hog production is possible with hog prices higher than $15.

The optimal conditions specified in the model would result in substantial reorganizations of individual farms in Iowa. For the programming solutions, the farm operators were assumed to have the same skills, to have perfect knowledge of the alternatives and to maximize profits. These assumptions caused the variation of optimum plans among farms to be less than is found in actual farm plans. The optimum farm plans differed among farms only because the ratios of the quantities of land, labor, and capital varied, as did the quality of the land. Thus, some farms did not specialize in beef production, pork production, and cash crops at a given set of prices.

The study results show an intra-Iowa distribution of agricultural production quite different from the actual distribution in some instances. Compared with the actual distribution of production, the optimum solutions showed a heavier concentration of beef cattle in southern, southeastern, and northeastern Iowa where pasture is relatively abundant. There also was a heavier concentration of hogs in northern and central Iowa where feed grains are abundant. Compared with the actual distribution of crop acres, the optimum solutions generally showed a heavier concentration of soybean acreage in area 4 (north-central Iowa) and a heavier concentration of corn acreage in areas 7 and 8 (northern and eastern Iowa).

The technical conditions and allocation principles also have important implications for farm income. The costs of producing a specified quantity of output were reduced under the technology of the model. Given the low aggregate demand elasticity, farm income would be lower if all farmers met the conditions specified in the model. On the other hand, if Iowa farmers could attain the optimal resource allocations and plans specified in the model and if the resulting large production of farm products could be sold at the average price levels for the last 10 years, aggregate farm income could be doubled.

One objective of this study was to estimate the aggregate effect of the trend in farm size on optimal production and resource use. Hence, the largest representative farm in each of the 10 areas was used to represent all farms in the area. By using fewer but larger representative farms, the aggregate farm-labor supply was reduced, but little change was made in the aggregate supply of capital. The net result was an average reduction of about 20 percent in optimal hog production over the 40 price combinations used in the model. Optimal beef production, however, increased in some solutions and decreased in others. Since hog production was more labor-intensive than beef production, the reduction in the labor supply affected the optimal production of pork more than it did beef. Aggregate farm profit was nearly the same before and after this adjustment in the representative farms was made. But profits per farm were considerably higher after the adjustment because of the reduced farm numbers.

The second objective of this study was to evaluate the effect on Iowa's agricultural production potential of the assumed increase in the level of farm technical efficiency. This was done by changing one assumption in the model and recomputing all the results. Average technical efficiency was assumed instead of advanced technical efficiency. A comparison of the results from the *average*-technical-efficiency model with the results from the *advanced*-technical-efficiency model showed that the difference in technical efficiency had a great impact upon Iowa's agricultural production potential. If all farmers were limited to using production techniques commonly used during 1957-1961, the production potential of Iowa agriculture would not greatly exceed actual production. But if every farmer in Iowa were to use the best production techniques known in 1961, the production potential would greatly exceed actual production levels.

Thus, our results suggest that, with an increase in the level of technology and perfect knowledge of alternatives by farmers, production of hogs, cattle, grains, and soybeans could be greatly increased from the existing stock of resources on Iowa farms. Alternatively, the current production level could be achieved with the investment of substantially fewer resources. The results indicate that Iowa farmers have the potential to substantially increase production--and incomes--in the event that the demand for Iowa farm products should substantially increase through world food or related needs.

Potential Agricultural Production and Resource Use in Iowa[1]

by Jerry A. Sharples, Earl O. Heady, and Mahmoud M. Sherif[2]

Changes in economic conditions and the rapid rate of technological advance in agriculture constantly force adjustments on individual farmers and the agricultural industry. Shifts in product prices and factor costs encourage farmers to consider alternative ways of increasing their incomes, such as intensifying, shifting to alternative enterprises, increasing efficiency, or leaving agriculture. An optimal decision for the individual farmer depends on the alternatives open to him. Thus, farmers need continuing research on adjustment alternatives.

The agricultural industry as a whole is also in constant need of adjustment. For example, the current rate of return to labor in agriculture, relative to the rate of return in other industries, justifies a movement of labor out of a agriculture. Similarly, the relative productivity and prices of labor and machine capital continue to invite a substitution of capital for labor and an enlargement of farm size.

Within this setting, farm policy-makers also try to derive farm programs that allow economically justified adjustments to take place in the industry, but at a rate more nearly optimal for society. Thus, policy-makers also have a continuing need for research on (among other things) the potential supply of agricultural commodities and the potential adjustment opportunities in agriculture.

One question of particular interest both to farmers and to policy-makers is: "What is the supply or production potential for agricultural commodities if government programs were removed and all farmers adopted the most efficient methods of production currently known?" Knowledge of this supply potential is needed for two reasons: (a) to determine how large the potential adjustment problem really is so that policy needs can be anticipated and (b) to evaluate the potential of U.S. agriculture to help feed large segments of the world. The latter research need has been a recent development. Since World War II, the "farm problem" in the United States has been one of surplus production. But because of the changing economic conditions and government production-control programs, the surplus stocks had been essentially eliminated by the mid-60's. Large amounts of unemployed and underemployed resources, however, still remain in agriculture, and the gap between actual production and potential production may still be wide. Studies such as ours can provide knowledge for a better assessment of production and adjustment potentials and needs that will prevail over future decades.

The results of this study are important for policy decisions because they indicate that future production potential is large. Accordingly, it is excepted that some forms of government programs will be necessary if farm prices and net farm income of the feed grain-livestock sector of the economy are to be maintained at current or acceptable levels. This finding is important relative to other propositions of recent years, which suppose that all existing production capacity will be absorbed in the immediate future by demand growth, an immediate cessation of government programs thus being possible.

OBJECTIVES

The general objectives of this study are to construct a research background for development and appraisal of farm programs and to provide the economic information needed by individual farmers in making adjustments in their systems of farming during the next few years.

The more specific objectives of the analysis are:

1. To derive profit-maximizing farm organizations for representative farms in Iowa at various hog and beef cattle prices and at two levels of technical efficiency, termed *average* and *advanced;*
2. To derive optimal aggregate production and resource use paterns for the agricultural industry in Iowa;
3. To compare the normative intra-Iowa location of production of the major agricultural commodities with the actual location of production;
4. To show the effect of optimal production practices on aggregate farm income in Iowa;
5. To evaluate the aggregate effect of farm-size adjustments on optimal production and resource use in Iowa; and
6. To evaluate the effect on Iowa's agricultural production potential of an increase in the level of farm technical efficiency.

OPTIMAL AGGREGATE SUPPLY FUNCTIONS FROM LINEAR PROGRAMMING

There are several ways of estimating supply. Predictive supply estimates can be derived from time-series models by using aggregate data. Normative supply functions can be derived from aggregate data or built up from normative individual farm supply functions.

[1] Project 1405, Iowa Agriculture and Home Economics Experiment Station, Center for Agricultural and Economic Development and Farm Production Economics Division, U.S. Department of Agriculture, cooperating. A contributing project to North Central Regional Research Project NC-54, "Supply Response and Adjustments for Hog and Beef Cattle Production in the Corn Belt."

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A discussion of the various methods is presented by Heady et al. (10). Since our study focused on the potential supply of both the individual farms and the state, a normative model was used to derive Iowa supply functions from the aggregation of normative linear-programming farm-supply functions.

The theory of using linear-programming models as the basis for estimating regional supply functions by aggregating representative farm-supply functions was outlined by Plaxico (14). An initial study using linear-programming models from representative farms to estimate an aggregate supply function was made by Krenz, Heady, and Baumann for the Des Moines milkshed (12). The theory, problems, and advantages of the model were futher discussed by McKee and Loftsgard (13) and by Barker (3).

The first of a series of cooperative regional studies on supply estimation was started in 1959 by the agricultural experiment stations in the Lake States and Southern States. Later the Corn Belt, northeastern, western, and Great Plains regions initiated similar cooperative projects. The Farm Production Economics Division, Economic Research Service, U.S. Department of Agriculture, also participated in the regional projects.

In each instance, the regional committees chose to use a model based on the aggregation of linear-programmed supply functions from representative farms.

Large amounts of research funds and manpower have been recently invested in research based on this model. The USDA and most of the state agricultural experiment stations now have agricultural economists and research funds invested in these regional cooperative projects.[3]

The procedure used in our study consisted of three steps: (a) The sample farms for the state were stratified, with a representative farm being defined for each stratum. A resource complement was then defined for each representative farm. [4] (b) An optimal organization for each representative farm at various combinations of hog and beef cattle prices was computed by linear programming. (c) For each set of hog and cattle prices, various charcteristics of the optimal organizations of the representative farms were aggregated to give state totals. The quantity of hogs sold, for example, could be aggregated across all the representative farms for an estimate of the optimum quantity of hogs sold in Iowa.

To calculate optimum production of the major agricultural products (corn, soybeans, oats, hay, hogs, and cattle) on each representative farm, the following assumptions were used: (a) A time period long enough for the farmer to adjust his enterprise size and mix, but not long enough for him to change his farm size. (b) All farms were owner-operated. (c) The operator had knowledge of all currently known production practices. (d) The operator did not restrain his plans because of uncertainty, and prices and yield coefficients were taken as known parameters. (e) The objective of the operator was to maximize profits. (f) The individual farm operator could not influence the market price of inputs or products. These assumptions are consistent with economic theory of the firm in a perfectly competitive market.

Profit-maximizing solutions were obtained for all representative farms at 40 combinations of hog, cattle, and soybeans prices. The prices of hogs varied from \$10.40 to \$15 per hundredweight, and the price for choice beef cattle varied from \$16 to \$24 per hundredweight. Two prices of soybeans, \$2 and \$2.35, were used. Relative to actual Iowa production, the model suggested the potential of substantial increases in production at historical prices levels. Thus, relatively low livestock prices were put into the model to obtain aggregate livestock supply functions over a relevant quantity range.

REPRESENTATIVE FARMS

The procedure used in defining representative farms was (a) take a sample of resources on individual farms; (b) array the farms by two of the most important factors affecting production response--type of soil and size of farm—and then stratify the farms into 10 soil types and three size groups[5]; and (c) define a representative farm for each cell of the stratification. This procedure led to the definition of 31 representative farms. Each of these steps will be described in detail.

The Sample

Because of prohibitive costs, and the study area's size, a survey of farms was not considered feasible. As an alternative, a sample of primary farm data was obtained from the Bureau of Census. These data were on an individual-farm basis and were a 5-percent random sample of all Iowa farms. Individual farm information was obtained from the Bureau of Census on the following farm characteristics: land use, tenure, farm type, labor use, cash expenditures, and major implements.

Only economic classes I to V, "cash grain," "general," and "livestock other than dairy or poultry" farms were included in the study.[6] And these farms are called "type A" farms in this report. Table 1 shows the percentages of resources and production on type A farms in 1959.

[3] Many of the results of the regional adjustment studies have been published. The Lakes States dairy study results are summarized in one regional publication (18). The S-42 committee has also published two reports containing aggregate results (19,20). State publications containing aggregate supply functions for subregions have also been written. Examples are: Andersen and Heady (1), Brees and Colyer (4), Gates and Kottke (7), Goodwin, Plaxico, and Lagrone (6), and Hatch and Moore (8).

[4] Because of the "length of run" assumed in this type of analysis and because of the aggregation problems involved, the size of farm, in acres, is fixed.

[5] In one soil-type classification, four farm sizes were defined, rather than three.

[6] The economic class and farm type definitions are from the 1959 Census of Agriculture (21).

The Stratification Procedure

After farm data were obtained, the next step was to stratify the farms. The objective was to group the farms by their expected adjustment response patterns. All farms thought to have similar adjustment alternatives and limitations were placed in the same group.

The first factor considered to have a major influence upon farmers' alternatives and limitations was soil type. Iowa was divided into 10 major soil areas with the boundaries following county lines (fig. 1).[7]

A cross-stratification of farms was then made by farm size. In all but one area, area 2, the farms were divided into three size categories: small, less than 140 acres; medium, from 140 to 240 acres; and large, over 240 acres. In area 2, a forth category was delineated for very large farms -- over 450 acres.

Thus, 31 strata were constructed. Further substratifications of the farms would have added substantially to project costs and time without giving proportionate benefits.[8]

Construction of Representative Farms

Representative farms were constructed from each of 31 strata. The objective was to define "representative" rather than "average" farms. The average farm concept would have been appropriate for the specific purpose of estimating optimal production for the state, but since individual farm analysis was also wanted, the representative farm concept was used. Thus, the "mode average," rather than the arithmetic mean, was used for the analysis.

Since the representative farms were "typical" rather than "average," there were some discrepancies in the aggregated data. For example, suppose that there are 1,000 farms in one stratum with a total of 300,000 acres of cropland. The typical farm in this example has 295 acres. Several very large farms are dropped from the stratum in the process of defining a typical farm. If this stratum is aggregated on the basis of actual farm numbers, the cropland acreage will be estimated as only 295,000 acres (1,000 x 295). If it is aggregated on the basis of cropland acres, the farm numbers will be estimated as 1,017 (300,000 ÷ 295). In this model, aggregate production of crops and livestock in Iowa is more a function of cropland acres than number of farms. Thus, aggregation coefficients were on a basis of cropland acres, rather than actual farm numbers in a stratum. The actual aggregation coefficients used in this study are shown in table 2.

Descriptions of the representative farms, based on the individual farm census data, were not complete. The census did not have data on farm facilities or on the farm financial position. These data were obtained

[7] The boundaries were drawn with the help of Professor William D. Shrader, Department of Agronomy, Iowa State University of Science and Technology.

[8] For an evaluation of the method of stratification used in this study, see Sharples, Miller, and Day (16).

Table 1. The percentages of various items represented by type A farms, Iowa, 1959.

	Percentages represented by		
Item	Type A farms	Other farms	All farms
Number of farms	78%	22%	100%
Cropland harvested	92	8	100
Acres of corn harvested	93	7	100
Acres of soybeans harvested	96	4	100
Acres of oats harvested	92	8	100
Number of cattle and calves (including dairy)	90	10	100
Number of hogs and pigs	92	8	100
Value of all products sold	91	9	100

Source: U.S. Department of Commerce. Bureau of the Census. Census of Agriculture, 1959. Vol. 1:16. State Table 18. U.S. Gov. Print. Office. Washington, D. C. 1961.

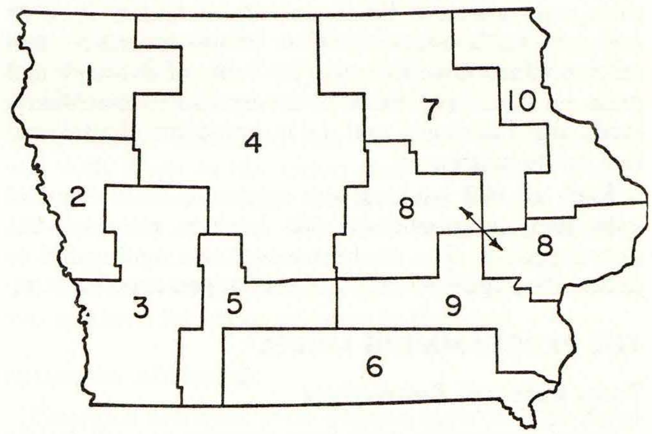

Fig. 1. Ten soil-area county groups in Iowa.

Table 2. Aggregation coefficients by representative farms.[a]

Area and farm number	Aggregation coefficient	Area and farm number	Aggregation coefficient
Area 1	11,843	Area 6	10,936
Farm 1	2,145	Farm 17	1,735
Farm 2	5,631	Farm 18	3,472
Farm 3	4,067	Farm 19	5,729
Area 2	5,923	Area 7	17,952
Farm 4	1,244	Farm 20	5,205
Farm 5	2,444	Farm 21	8,049
Farm 6	1,539	Farm 22	4,698
Farm 7	696		
Area 3	13,843	Area 8	17,792
Farm 8	2,796	Farm 23	4,539
Farm 9	5,531	Farm 24	7,952
Farm 10	5,516	Farm 25	5,301
Area 4	32,610	Area 9	14,694
Farm 11	6,718	Farm 26	7,067
Farm 12	14,252	Farm 27	4,304
Farm 13	11,640	Farm 28	3,323
Area 5	7,322	Area 10	8,226
Farm 14	1,726	Farm 29	2,293
Farm 15	2,797	Farm 30	3,687
Farm 16	2,799	Farm 31	2,246
Total			141,141

[a] The aggregation coefficient is the number of farms represented by one representative farm.

by two mail surveys, one to county extension directors and one to rural Iowa bankers.

A facilities questionnaire was constructed for each representative farm and included a description of land use, farm size, farm type, and annual cash expenditures for specified items. Each of the 100 county extension directors received questionnaires concerning all the representative farms in his area. And each was asked to estimate the type and the capacity of the hog-farrowing, hog-feeding, and beef-feeding facilities on each representative farm. All 100 county extension directors completed the questionnaires. The mode was used to determined the facilities for the representative farms.

Another questionnaire, containing the same descriptive information as the facilities questionnaire, was prepared for each representative farm. In this mail survey, the following information was requested for each representative farm: (a) liquid assets such as cash, stocks, bonds, cash value of life insurance, and other nonfarm investments; (b) value of livestock and grain on hand; (c) value of investment in machinery, land, and buildings; and (d) short-term chattel and real estate mortgages.

Each of 672 bankers was contacted and supplied with two questionnaires; 333 bankers returned 644 questionnaires. The modal concept was again used to define the capital situation of each representative farm.

THE PROGRAMMING MODEL[9]

Farm Resource Restrictions

Farm production and farm income are ultimately limited by farmer's resources. Therefore, it was necessary to establish resource restraints on each representative farm. Resource restraints used for each of the 31 representative farms are shown in appendix table A-1.

In establishing these restraints, it was necessary to distinguish among soil types that had limitations with respect to crops grown. The cropland in each of the 10 geographic areas of the state was divided into three productivity classes: class 1 land, on which continuous row-cropping was allowed; [10] class 2 land that had a maximum of 2 years of row-cropping in a 4-year rotation; and class 3 land that had a maximum of 1 year of row crops in a 4-year rotation. Each representative farm in a given area was given the same percentage distribution of these three land classes as the area as a whole. In areas 1 (predominantly Galva, Primghar, and Sac soils), 4 (Clarion and Webster soils), 7 (Carrington and Clyde soils), and 8 (Tama and Muscatine soils), class 3 cropland was omitted because it represented a very small percentage of the total cropland.

The labor resources were divided into two categories: family labor (including the operator) and hired labor. Small farms were given a family labor supply of one full-time operator. Medium-sized farms were given one full-time operator, plus the equivalent of one high-school boy. All large farms were given a family labor supply of 1.2 operators, plus the equivalent of one high-school boy. For each farm, overhead labor (labor related to the farm operation but not a linear function of any of the enterprises) was subtracted from the total amount of family labor to give the family labor data shown in appendix table A-1.

The maximum amount of hired labor allowed each representative farm was the average of the actual amount of hired labor used in 1959, multiplied by the factor 1.2; i.e., a potential 20-percent increase in hired labor over 1959. Labor could be hired in any month of the year. No monthly limitations were placed upon the hired labor, but the total amount for the year was limited to the amount prescribed.

Capital for operating and investment purposes was represented by a restraint built up from (a) cash and assets that could readily be converted to cash and (b) chattle mortgage credit. All the farmer's Jan. 1, 1959, inventory of crops and livestock was converted to cash. And this cash was then made available for investment in any enterprise or combination of enterprises found most profitable.

Chattle credit could also be used by the farmer as a source of operating and investment capital. The maximum amount of chattle credit that could be obtained was 50 percent of Jan. 1, 1959, inventory of machinery, minus any outstanding debts on machinery.

The representative farms were given an adequate inventory of farm machinery to prepare the seedbed and plant and cultivate crops. Some data on major machinery ownership were furnished by the Bureau of Census's 1959 sample of Iowa farms. These data showed that (a) farms of all sizes generally had corn pickers, (b) the typical medium-sized farm also had a combine, and (c) the typical large farm had a corn picker, combine, and baler.

Alternative Uses of Farm Resources

On each model farm, resources could be invested in various farm and nonfarm activities. Only activities most likely to compete for the farmers' resources were considered.[11] The farmer was given, in the formulation of the model, the choice of raising hogs, beef cows, beef feeders, or any of the following crops: corn, soybeans, oats, or hay. Purchasing activities for buildings and facilities were included to allow for the expansion of livestock production. The acres of land on the farm, however, were held constant. Opportunities for off-farm investment of capital also were included in the model.

Crop costs were unique for each representative farm because costs were affected both by farm size and by soil type. But the costs of raising a given type and

[9] For more details on the programming model, see Sharples (15) and Sherif (17).

[10] The row crops considered were soybeans and corn.

[11] Only cash-grain and livestock farms are considered in this analysis. The operators of these farms generally do not consider the alternatives of going into dairy, vegetable, poultry, or other specialized enterprises. Thus, these alternatives are not included in the analysis.

quantity of livestock did not vary by size of farm or by area of the state.

CROPPING ACTIVITIES

As stated, three classes of cropland were considered. Specific rotations were allowed for each class of land. On class 1 cropland, five rotations were defined: (a) continuous corn, (b) corn-soybeans, (c) corn-corn-oats-meadow, (d) corn-soybeans-oats-meadow, and (e) corn-soybeans-soybeans-oats-meadow. Four rotations were defined for class 2 cropland: (a) corn-corn-oats-meadow, (b) corn-soybeans-oats-meadow, (c) corn-soybeans-oats-meadow-meadow, and (d) continuous meadow. There were two alternative rotations allowed for the poorest (class 3) cropland: (a) corn-oats-meadow-meadow and (b) continuous meadow. Corn could be harvested either as grain or silage. The meadow could be grazed or harvested as hay.

Crop yields and rates of fertilizer application differed for each rotation. For example, the corn yield and rate of fertilization of the CCOM rotation on class 1 cropland differed from the corn yield and rate of fertilization on the CCOM rotation of class 2 cropland. The fertilizer rates represent agronomists' recommendations as to the most profitable levels to be applied on the various Iowa soils. One application of a weed-control chemical was specified for all corn. One application of an insect-control chemical also was specified for the corn acreage.

HOG ACTIVITIES

Twelve hog-producing activities were included in the linear-programming model. Each of the activities had the following common characteristics: 8 pigs per litter, 7 hogs sold at 225 pounds 6 months after farrowing, 1 gilt kept for replacement, and the sow sold at 400 pounds, 3 months after farrowing.

The 12 activities were differentiated on the basis of types of feeding and farrowing facilities used and with respect to farrowing date. The three types of farrowing and feeding facilities were: (a) portable farrow and portable feed, (b) confinement farrow and confinement feed, and (c) confinement farrow and portable feed. The four farrowing months were February, May, August, and November. Additional farrowing and feeding facilities could be purchased.

BEEF ACTIVITIES

Alternative beef calf-fattening, yearling-fattening, and cow-calf activities were developed for the representative farm linear-programming model. Purchasing activities for beef housing and feeding facilities also were included. The calf- and yearling-fattening activities were divided according to feeding systems and rations. The feeding systems were (a) hand feeding with portable feed bunks and (b) power unloading wagon with fenceline feed bunks. The ration was either with or without corn silage.

In the calf-fattening activities, the calves were purchased (or transferred from the cow-calf activities) in October to grade good to choice and sell choice. Calves were fed in drylot or exclusively on pasture. The drylot calves began with a 10-day feeding period of hay, with some supplemental grain and protein. They were then placed on a diet of stalk and meadow residue along with a light feeding of grain, hay, and protein supplement until Dec. 15. They were wintered in drylot and fed a ration of grain, protein supplement, and hay. Silage could be substituted for some of the hay and corn. After March 15 the calves were full fed on grain, protein supplement, and hay.

The calves fed exclusively on pasture were handled the same as drylot calves until May 15. Then they were placed on pasture and full fed on grain. Yearlings were purchased in October or April and fed out in 165 days, if silage was included in the ration, or 160 days, if silage was not included.

The model contained two beef cow-calf activities, one with silage in the ration and one without silage. The calves could either be fattened by any of the calf-fattening activities described or sold in October at 430 pounds. A 95-percent calf crop was built into the beef cow-calf activities. One replacement heifer was retained for every six cows in the herd.

FINANCIAL ACTIVITIES

Financial activities were defined such that the farm year was divided into two capital-use periods. Period 1 was October through March, and period 2 was April through September. The two periods were used to allow earnings from production activities during the first half of the farm year to be invested in production activities for the second half. Activities were included to allow cash to be invested off the farm at 5-percent interest, if the investment was for two periods, or at an annual rate of 4 percent, if the investment was for only one period. Borrowing was allowed with the use of chattels as collateral at 7-percent interest.

AGGREGATE (STATEWIDE) RESULTS ASSUMING ADVANCED TECHNICAL EFFICIENCY[12]

The aggregate results for the advanced-technical-efficiency model are discussed in four sections. In the first section, the 40 aggregate solutions are presented. A general description is included of the differences and similarities of the 40 solutions. In the second section, 4 of the 40 solutions are presented in detail to show the production potential of Iowa agriculture. Two solutions—26 and 27—show the quantities of re-

[12] For the description of the linear programming results for one of the representative farms in the study, see pages 34 to 55 of Sharples (15).

sources needed, under ideal conditions, to produce near-current levels of output of grains, soybeans, hogs, and cattle in Iowa. Solution 28 shows Iowa's potential for maximizing beef cattle production, against the prices and costs specified, and solution 37 shows similarly the potential for maximizing hog production.

In the third section, comparisons are made of the implication of each of these solutions for aggregate farm income.

In the fourth section, the model is revised to evaluate the aggregate effect of farm-size adjustments on optimal production and resource use.

Table 3. Optimum aggregate farm production and resource use in Iowa in 40 solutions with different price combinations under advanced technology.

Item	Unit	Solution number				
		1	2	3	4	5
Prices						
Soybeans	dollars/bu.	2.00	2.00	2.00	2.00	2.00
Hogs	dollars/cwt.	10.40	10.40	10.40	10.40	10.70
Cattle	dollars/cwt.	16.00	17.00	18.00	20.00	16.00
Crops						
Corn	1,000 acres	18,345	18,193	18,041	17,298	18,369
Soybeans	1,000 acres	617	785	836	536	593
Oats	1,000 acres	1,947	1,904	1,781	1,234	1,947
Rotation meadow	1,000 acres	2,694	2,721	2,945	4,535	2,694
Beef						
Cows	1,000 head	2,191	2,088	1,234	145	2,078
Calves sold	1,000 head	641	0	0	0	675
Calves purchased	1,000 head	0	537	5,003	14,815	0
Total live beef sold	million lbs.	1,516	2,649	6,535	15,821	1,370
Hogs						
Total live hogs sold	million lbs.	0	0	0	0	5,759
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	0	0	0	0
Beef housing	1,000 a.u.[a]	43	164	1,008	5,096	4
Beef feeding	1,000 head	0	0	0	4,300	0
Resources						
Borrowed funds	million dol.	0	0	24	479	0
Cash invested off farm	million dol.	1,395	1,334	979	125	1,323
Labor hired	million m.h.[b]	13	14	13	22	16
Operator and family labor not used	million m.h.	158	149	138	68	125
Revenue	million dol.	1,310	1,334	1,372	1,543	1,331

[a]Animal units
[b]Man-hours.

Item	Unit	Solution number				
		6	7	8	9	10
Prices						
Soybeans	dollars/bu.	2.00	2.00	2.00	2.00	2.00
Hogs	dollars/cwt.	10.70	10.70	10.70	11.00	11.00
Cattle	dollars/cwt.	17.00	18.00	20.00	16.00	17.00
Crops						
Corn	1,000 acres	18,187	18,081	17,321	18,397	18,275
Soybeans	1,000 acres	785	805	538	586	682
Oats	1,000 acres	1,899	1,790	1,246	1,967	1,902
Rotation meadow	1,000 acres	2,732	2,926	4,498	2,653	2,744
Beef						
Cows	1,000 head	1,992	1,163	145	1,783	1,556
Calves sold	1,000 head	0	0	0	550	1
Calves purchased	1,000 head	566	5,075	14,657	0	1,101
Total live beef sold	million lbs.	2,585	6,538	15,654	1,208	2,724
Hogs						
Total live hogs sold	million lbs.	5,191	4,843	1,994	11,390	11,087
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	0	0	0	0
Beef housing	1,000 a.u.	118	937	4,994	4	12
Beef feeding	1,000 head	0	0	252	0	0
Resources						
Borrowed funds	million dol.	0	21	469	0	0
Cash invested off farm	million dol.	1,261	898	108	1,169	1,108
Labor hired	million m.h.	16	15	23	21	20
Operator and family labor not used	million m.h.	119	109	58	99	93
Revenue	million dol.	1,353	1,391	1,550	1,369	1,390

Forty Aggregate Solutions

The optimal plans at each of the 40 price combinations were aggregated over the representative farms to give the Iowa results shown in table 3. The first three entries for each solution in table 3 are the prices of soybeans, hogs, and cattle used for that solution.

The figures in table 3 indicate that the optimum organization of agriculture in Iowa differs greatly with price changes in soybeans, hogs, and cattle.

AGGREGATE CROP PRODUCTION

Crop production changes considerably over the 40 solutions in table 3. Corn acreage ranges from a low of 11.9 million acres in solution 27 to a high of 18.7

Table 3. (Cont'd).

Item	Unit	Solution number 11	12	13	14	15
Prices						
Soybeans	dollars/bu.	2.00	2.00	2.00	2.00	2.00
Hogs	dollars/cwt.	11.00	11.00	11.50	11.50	11.50
Cattle	dollars/cwt.	18.00	20.00	16.00	17.00	18.00
Crops						
Corn	1,000 acres	18,106	17,456	18,478	18,428	18,257
Soybeans	1,000 acres	775	536	505	547	653
Oats	1,000 acres	1,797	1,323	1,978	1,945	1,842
Rotation meadow	1,000 acres	2,924	4,287	2,642	2,682	2,852
Beef						
Cows	1,000 head	925	163	1,116	767	634
Calves sold	1,000 head	0	0	318	43	0
Calves purchased	1,000 head	5,337	13,779	226	1,708	4,549
Total live beef sold	million lbs.	6,571	14,734	1,055	2,571	5,467
Hogs						
Total live hogs sold	million lbs.	10,408	5,967	21,679	21,224	18,352
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	299	244	145
Hog feeding	1,000 pigs	0	0	18,328	17,264	11,760
Beef housing	1,000 a.u.	755	4,451	0	5	333
Beef feeding	1,000 head	0	3,284	0	0	0
Resources						
Borrowed funds	million dol.	11	417	7	7	35
Cash invested off farm	million dol.	758	122	629	574	394
Labor hired	million m.h.	20	26	30	29	28
Operator and family labor not used	million m.h.	79	43	57	56	50
Revenue	million dol.	1,428	1,569	1,471	1,483	1,510

Item	Unit	Solution number 16	17	18	19	20
Prices						
Soybeans	dollars/bu.	2.00	2.00	2.00	2.00	2.00
Hogs	dollars/cwt.	11.50	12.00	12.00	12.00	12.00
Cattle	dollars/cwt.	20.00	16.00	17.00	18.00	20.00
Crops						
Corn	1,000 acres	18,043	18,677	18,663	18,653	18,322
Soybeans	1,000 acres	277	311	326	330	283
Oats	1,000 acres	1,601	2,012	1,997	1,988	1,765
Rotation meadow	1,000 acres	3,682	2,603	2,617	2,631	3,232
Beef						
Cows	1,000 head	289	748	681	666	288
Calves sold	1,000 head	0	341	309	43	0
Calves purchased	1,000 head	10,935	761	1,158	2,349	8,830
Total live beef sold	million lbs.	11,847	1,236	1,639	3,145	9,623
Hogs						
Total live hogs sold	million lbs.	12,237	26,292	25,897	24,415	17,402
Livestock facilities added						
Hog farrowing	1,000 sows	0	739	801	646	226
Hog feeding	1,000 pigs	3,480	28,480	27,904	24,008	11,136
Beef housing	1,000 a.u.	2,842	0	0	1	1,566
Beef feeding	1,000 head	1,177	0	0	0	561
Resources						
Borrowed funds	million dol.	292	100	100	146	293
Cash invested off farm	million dol.	103	320	282	231	85
Labor hired	million m.h.	30	50	47	48	45
Operator and family labor not used	million m.h.	37	55	55	53	39
Revenue	million dol.	1,617	1,586	1,596	1,611	1,686

million acres in solution 17. Soybeans are produced at all 40 price combinations. Soybean acreage ranges from 277 thousand acres to nearly 7 million acres and oat acreage ranges from 1.1 million acres to 2.0 million acres. In 1965, Iowa farmers raised 9.9 million acres of corn for grain, 4.8 million acres of soybeans, and 2.0 million acres of oats.[13]

In the model, rotation meadow can be used for pasture or for hay production. In solutions 28 and 32, the solutions in which the most beef is sold, rotation meadow acreage also is highest (5.9 million acres). Meadow acreage drops to a low of 2.6 million acres in solutions 21 and 22. Though not shown in table 3, hay production is largest (16 million tons) in solu-

[13] In 1965, Iowa farmers raised 0.5 million acres of corn for nongrain uses. They also diverted 3.5 million acres for government payments through the Feed Grain Program. Assuming that the diverted land would have been planted to row crops (corn or soybeans), 18.7 million acres were used for row crops in 1965. Over the 40 solutions to the model, row crop acreage varied from 15.9 million to 19 million acres.

Table 3. (Cont'd).

Item	Unit	Solution number				
		21	22	23	24	25
Prices						
Soybeans	dollars/bu.	2.00	2.00	2.00	2.00	2.35
Hogs	dollars/cwt.	13.00	13.00	13.00	13.00	10.70
Cattle	dollars/cwt.	16.00	17.00	18.00	20.00	16.00
Crops						
Corn	1,000 acres	18,445	18,445	18,424	18,347	12,048
Soybeans	1,000 acres	543	543	564	641	6,914
Oats	1,000 acres	2,014	2,014	1,992	1,971	1,678
Rotation meadow	1,000 acres	2,601	2,601	2,622	2,644	2,963
Beef						
Cows	1,000 head	672	1,016	988	646	2,182
Calves sold	1,000 head	531	542	373	7	763
Calves purchased	1,000 head	0	33	280	1,982	0
Total live beef sold	million lbs.	112	493	922	2,788	1,386
Hogs						
Total live hogs sold	million lbs.	27,803	27,485	27,100	25,323	5,694
Livestock facilities added						
Hog farrowing	1,000 sows	1,121	1,058	1,031	879	0
Hog feeding	1,000 pigs	31,784	30,832	29,968	26,104	0
Beef housing	1,000 a.u.	0	0	0	10	5
Beef feeding	1,000 head	0	0	0	0	0
Resources						
Borrowed funds	million dol.	166	173	177	226	0
Cash invested off farm	million dol.	272	197	195	178	1,376
Labor hired	million m.h.	48	57	56	48	11
Operator and family labor not used	million m.h.	52	52	52	51	124
Revenue	million dol.	1,852	1,858	1,866	1,893	1,368

Item	Unit	Solution number				
		26	27	28	29	30
Prices						
Soybeans	dollars/bu.	2.35	2.35	2.35	2.35	2.35
Hogs	dollars/cwt.	10.70	10.70	10.70	11.00	11.00
Cattle	dollars/cwt.	17.00	18.00	24.00	16.00	17.00
Crops						
Corn	1,000 acres	11,972	11,941	12,985	12,287	12,152
Soybeans	1,000 acres	6,985	6,960	2,938	6,695	6,823
Oats	1,000 acres	1,632	1,535	1,768	1,713	1,655
Rotation meadow	1,000 acres	3,014	3,167	5,912	2,908	2,973
Beef						
Cows	1,000 head	2,063	1,428	156	1,910	1,725
Calves sold	1,000 head	0	0	0	632	10
Calves purchased	1,000 head	665	4,617	20,073	0	1,008
Total live beef sold	million lbs.	2,766	6,310	21,387	1,250	2,786
Hogs						
Total live hogs sold	million lbs.	4,932	4,468	0	10,629	10,139
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	0	0	0	0
Beef housing	1,000 a.u.	141	1,029	8,542	3	43
Beef feeding	1,000 head	0	0	9,516	0	0
Resources						
Borrowed funds	million dol.	0	11	1,799	0	0
Cash invested off farm	million dol.	1,304	933	0	1,226	1,159
Labor hired	million m.h.	11	12	32	15	15
Operator and family labor not used	million m.h.	118	108	34	100	94
Revenue	million dol.	1,391	1,429	1,991	1,405	1,426

tions 28 and 32 and smallest (0.8 million ton) in solution 37, of 16 million tons.

The aggregate results have policy implications for crop production. One of the pressing policy problems currently facing policy administrators is how to adjust the variables under their control to influence the amounts raised of corn, soybeans, and other crops to prevent crop surpluses or shortages. The results of this study, shown in table 3, point out two variables of special importance that affect the quantity of corn and soybeans that enter the program solution for Iowa: the corn-soybean price ratio and the hog-cattle price ratio.

Because of the agronomic restraints incorporated into the model, the maximum combined acreage of corn and soybeans allowed in Iowa is 19 million acres. Corn could be grown on all, but the maximum amount of soybeans allowed, again because of ag-

Table 3. (Cont'd).

Item	Unit	Solution number				
		31	32	33	34	35
Prices						
Soybeans	dollars/bu.	2.35	2.35	2.35	2.35	2.35
Hogs	dollars/cwt.	11.00	11.00	12.00	12.00	12.00
Cattle	dollars/cwt.	18.00	24.00	16.00	17.00	18.00
Crops						
Corn	1,000 acres	12,337	12,985	15,340	15,402	15,405
Soybeans	1,000 acres	6,602	2,938	3,648	3,587	3,583
Oats	1,000 acres	1,568	1,768	1,938	1,866	1,862
Rotation meadow	1,000 acres	3,095	5,912	2,676	2,748	2,753
Beef						
Cows	1,000 head	1,193	156	1,078	934	824
Calves sold	1,000 head	0	0	572	368	53
Calves purchased	1,000 head	4,685	20,073	325	828	2,295
Total live beef sold	million lbs.	6,149	21,387	844	1,470	3,233
Hogs						
Total live hogs sold	million lbs.	9,055	0	24,071	23,535	21,694
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	548	506	352
Hog feeding	1,000 pigs	0	0	24,080	22,568	18,208
Beef housing	1,000 a.u.	728	8,542	0	0	7
Beef feeding	1,000 head	0	9,516	0	0	0
Resources						
Borrowed funds	million dol.	0	1,799	59	57	56
Cash invested off farm	million dol.	860	0	451	430	312
Labor hired	million m.h.	15	32	40	36	34
Operator and family labor not used	million m.h.	84	34	55	55	53
Revenue	million dol.	1,461	1,991	1,602	1,612	1,627

Item	Unit	Solution number				
		36	37	38	39	40
Prices						
Soybeans	dollars/bu.	2.35	2.35	2.35	2.35	2.35
Hogs	dollars/cwt.	12.00	15.00	15.00	15.00	15.00
Cattle	dollars/cwt.	24.00	16.00	17.00	18.00	24.00
Crops						
Corn	1,000 acres	14,848	17,245	17,245	17,245	17,406
Soybeans	1,000 acres	2,425	1,743	1,743	1,743	1,481
Oats	1,000 acres	1,112	1,982	1,982	1,982	1,878
Rotation meadow	1,000 acres	5,219	2,632	2,632	2,632	2,838
Beef						
Cows	1,000 head	156	525	778	994	592
Calves sold	1,000 head	0	415	615	785	0
Calves purchased	1,000 head	17,189	0	0	0	3,446
Total live beef sold	million lbs.	18,341	89	130	167	4,280
Hogs						
Total live hogs sold	million lbs.	6,542	30,650	30,476	30,260	26,559
Livestock facilities added						
Hog farrowing	1,000 sows	0	1,219	1,232	1,194	813
Hog feeding	1,000 pigs	408	37,976	38,480	38,168	28,512
Beef housing	1,000 a.u.	6,668	0	0	0	217
Beef feeding	1,000 head	6,663	0	0	0	0
Resources						
Borrowed funds	million dol.	1,454	432	432	463	701
Cash invested off farm	million dol.	7	57	23	30	0
Labor hired	million m.h.	39	49	55	60	51
Operator and family labor not used	million m.h.	32	38	38	39	36
Revenue	million dol.	2,025	2,418	2,420	2,424	2,483

ronomic restraints, would be 9.7 million acres. Thus, the levels of technology and prices used in the model restricted corn and soybean acreage in Iowa to the programmed levels. The model did not include any acreage restriction program for supply-control purposes.

Of the 40 solutions obtained for Iowa, the ones with the highest corn acreage were those in which the price of soybeans was low relative to the corn price and which the price of hogs was high relative to the cattle price. (For example, see solutions 17 to 20 in table 3). The smallest corn acreage tended to be in solutions with high soybean price relative to corn price and high beef price relative to hog price. (For example, see solutions 25 to 32 in table 3).

The soybean-corn price ratio had a greater impact on corn (and soybean) acreage than did the hog-cattle price ratio. Solutions 6 and 26 were based on identical sets of assumptions except that the price of soybeans was $2 per bushel in solution 6 and $2.35 per bushel in solution 26. The corn price was held at $1 per bushel in both instances. By increasing the soybean price by 35 cents, corn acreage was reduced from nearly 18.2 million acres to about 12 million acres, but soybean acreage was increased from 785,000 acres to nearly 7 million acres. Additional linear-programming solutions for one of the representative farms indicated that, with low hog prices, $11 or less, an increase in soybean price to $2.50 would cause the statewide level of soybean production to approach 9 million acres. At higher hog prices, however, the soybean price would have had to increase to about $3 to have had 9 million acres of soybeans raised. Of course, a corn price other than $1 would have altered these results, but the relationship between corn and soybean acreage and the various crop and livestock price ratios would be the same as observed here.

Several of the factor-input assumptions contained in the model have aggregate implications. In the model, 1 pound of insecticide was applied to each acre of corn grown, and 1 pound of herbicide was applied to each acre of corn and soybeans grown. In solution 26, for example, 5,986 tons of insecticide and 9,478 tons of herbicide were used on corn and soybean acres in Iowa. The total cost of these two pesticides was 86 million dollars. But in solution 28, in which the total acreage of corn and soybeans was substantially less than for solution 26, the total cost of pesticides was reduced to 67 million dollars. In 1964, Iowa farmers applied 20 million dollars worth of pesticides on crops (2).

Recommended fertilization practices were built into the crop coefficients in the model. The results showed that, for the Iowa crop acreage shown in solution 26, a total of 364,000 tons of nitrogen (N), 92,000 tons of phosphorus (P), and 65,000 tons of potassium (K) would need to be applied. In 1964, Iowa farmers applied 273,000 tons of N, 90,000 tons of P, and 102,000 tons of K to their crops.[14] The optimum application of fertilizer changed considerably over the 40 solutions. In solution 40, for example, corn acreage was increased to 17.4 million acres, and 524,000 tons of N, 107,000 tons of P, and 72,000 tons of K were specified as optimal for the state.

AGGREGATE HOG PRODUCTION

Hogs were raised in 34 of the 40 aggregate solutions. No hogs were sold in solutions 1 through 4 ($10.40-hogs), in solution 28 ($10.70-hogs and $24-cattle) and solution 32 ($11-hogs and $24-cattle). In most instances, the spring pig crop was slightly larger than the fall pig crop. In those solutions in which relatively large numbers of hogs were raised, central farrowing and pasture fattening was the system most often selected in the programming computations.

In solution 37, hog marketings were the highest at 30.65 billion pounds. Iowa and the United States marketed 4.45 billion pounds and 18 billion pounds, respectively, in 1965. Thus, under the assumed conditions, the programmed solutions suggest that Iowa has the potential to produce 1.7 times the 1965 U.S. production of hogs. Solution 37 is discussed in detail later.

The quantities of hogs sold at three price levels in the aggregate solutions are shown as dots in fig. 2 and are labeled "advanced technical efficiency."[15] "Average technical efficiency" curves are discussed later. This figure shows the relationships among the prices of hogs, prices of cattle, and the aggregate quantities of hogs sold. Figure 2 shows the great potential for hog production that exists in Iowa. Many of the quantities exceed the amount of hogs sold in the United States in 1965. Only at hog prices below $11 does the quantity sold under advanced technology approach the actual sales of hogs in Iowa in 1965.

As one would have expected, the optimum quantity of hogs produced in Iowa increases as the price of hogs increases and as the price of beef cattle decreases. Figure 2 also shows that optimal hog production decreases more with a rise in beef cattle price from $18 to $20 than with a rise from $16 to $18. Below $12-hogs, the optimal supply curves for hogs appear very elastic. But above $13-hogs, the hog supply curves are very inelastic. The level of hog production in solutions 37 to 40 ($15-hogs) compared with solutions 21 to 24 ($13-hogs) suggests that the farm resources are nearly all used in hog production

[14] The 1964 fertilizer-use information for Iowa was obtained from preliminary results of a joint study by the Economic Research Service and Agricultural Research Service, USDA, and the Agronomy Department of Iowa State University. The three agencies were represented at Iowa State University by Jerry A. Sharples, Minoru Amemiya, and Regis Voss, respectively.

[15] Solutions 25 to 40 are omitted because the 35-cent increase in soybean price included in these solutions causes only a small shift in the curves to the left. The $17-cattle curve is omitted to keep the figure uncluttered. The curves shown in fig. 2 are pseudo-supply curves. Actual optimal supply "curves" would be stepped, but since only 4 to 6 observations are made on each curve, the true shapes of the curves are not known. The dots in fig. 2 represent the quantity-price locations of the solutions. The dots are connected by straight lines to give a general idea of the supply relationships.

at $13 and that little further increase in hog production is possible.

AGGREGATE BEEF PRODUCTION

Beef calves were fattened in all but four of the 40 aggregate solutions. These were the four solutions with the hog-cattle price ratio most unfavorable to beef production. Yearlings were fattened in only solutions 28, 32, 36, and 40—the solutions with $24-cattle. The maximum number of yearlings fed was only 32,000 head.

On the other hand, beef cow herds appeared in all 40 of the optimal solutions shown in table 3. The most beef cows were raised in solutions 1 and 25 (2.2 million head), and the fewest in solutions 4 and 8 (145,000 head). The optimum production of beef cows generally decreased as the price of hogs increased and as the price of beef increased. Beef feeders became more competitive with the beef cow herd for hay, pasture, and other resources as the price of beef increased. When cattle prices were low relative to hog prices, beef calves were sold rather than being fattened to slaughter weights.

Thirteen solutions show Iowa as a net *exporter* of beef calves. In the model, however, the assumption is made that there is a perfectly elastic demand for beef calves at the assumed price for calves.[16]

Over the 40 optimal solutions for Iowa, the total sales of cattle for slaughter ranged from 89 million pounds (solution 37) to 21.4 *billion* pounds (solutions 28 and 32). In 1965, Iowa marketed 4.7 billion pounds of cattle, and the United States marketed 44 billion pounds of cattle. Solutions 28 and 32 indicate that, under the assumed conditions of the model, Iowa has the potential to produce about half of the nation's supply of beef. These solutions are also discussed in detail in the next section.

Figure 3 shows the cattle price-cattle production relationships of 12 of the aggregate solutions under the assumptions of advanced technical efficiency. (Those for average technical efficiency will be discussed later). Figure 3 shows that Iowa has the potential to expand cattle production considerably. Solutions 28 and 32 (not shown on fig. 3) suggest that the "advanced technical efficiency" curves shown in fig. 3 would become very inelastic at about 22 billion pounds.

A comparison of cattle production at cattle prices below $20 in fig. 3 with hog production at hog prices below $13 in fig. 2, indicates that hog production, under optimal programming solutions, is much more elastic. The reason for the relative inelasticity of cattle production compared with hog production is the costs of production. Major costs per unit of hog production are constant as the sale price of hogs varies. But a major component of the cost of cattle production—the cost of the feeder calf—varies with the sale price of cattle. Thus, at the price levels specified in the model, the marginal cost curve for cattle production is steeper than the marginal cost curve for hog production.

[16] The sale and purchase price of calves associated with each cattle price level are shown in appendix table A-2.

AGGREGATE RESOURCE USE

The quantities of farm resources used in farm production also varied considerably over the 40 aggregate solutions for Iowa. Solutions 28 and 32 required the most capital. In these two solutions, all the liquid assets available on the representative farms for investment in the farm operation were used. An additional 1,345 million dollars was borrowed in period 1 (October to March), and 454 million dollars was borrowed in period 2 (April to September) to pay for costs of farm operation.[17] On the other hand, the least amount of capital was used for farming in solution 1 in which 967 million dollars of liquid assets were invested in farm production. In solution 1, 1.4 billion

[17] These figures on borrowed capital do not include farmers' debts on real estate or machinery.

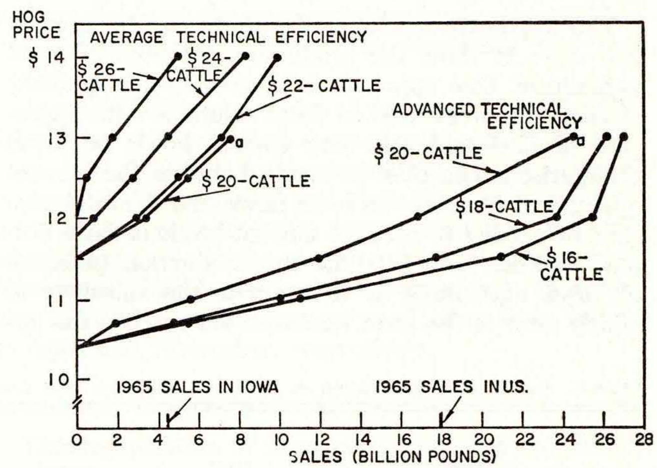

Fig. 2. Live hog sales in Iowa under optimum programmed solutions for advanced and average technical efficiency.

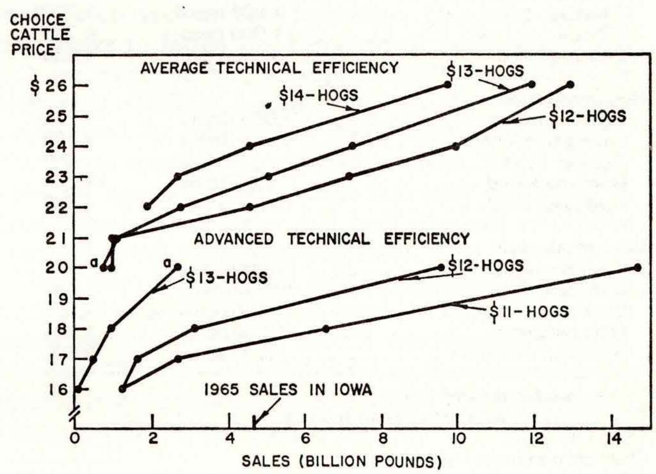

Fig. 3. Beef cattle sales in Iowa under programmed optimum solutions for advanced and average technical efficiency.

dollars were invested in an off-farm investment activity that yielded a return of 5-percent interest.

A total of 130,000 man-years of operator and family labor and 25,800 man-years of hired labor were available for employment in the farm production. The least labor was used in solution 1 (72,600 man-years), and the most labor was used in solution 39 (139,100 man-years). Some labor was hired and some family labor went unused in each of the 40 aggregate solutions. This happened because of (a) labor peaks and slack periods on each of the representative farms and (b) labor abundance on some representative farms and labor scarcity on others.

Aggregate "revenue"—gross sales, minus the variable costs of production—ranged from 1.3 billion dollars in solution 1 to about 2.5 billion dollars in solution 40. In 1965, the comparable figure for Iowa farmers was about 1.6 billion dollars.

The Production Potential of Iowa Agriculture as Shown in Four Aggregate Solutions

The aggregate results of the study can be used in two ways to show the production potential of Iowa agriculture. One approach is to examine the quantity of farm resources used in those solutions with aggregate production levels near current levels in Iowa. Comparisons can then be made between the current quantity of resources on Iowa farms and the minimum amount needed to produce current levels of farm output. Another way to show the production potential of Iowa agriculture is to examine the solutions in which most of the farm resources are used in the optimal production of farm products. Each of these two approaches is discussed below, with the first approach first discussed.

ANALYSIS OF SOLUTIONS THAT APPROXIMATE ACTUAL LEVELS OF PRODUCTION IN IOWA

In 1965, 4,452 million pounds of pork and 4,688 million pounds of beef were marketed from Iowa farms. Iowa farmers also raised 9.9 million acres of corn and 4.8 million acres of soybeans. Of the 40 solutions shown in table 3, solutions 26 and 27 come the closest to these levels of production. A comparison of solutions 26 and 27 with actual farm production in Iowa is shown in table 4. The main difference between the two solutions is the level of beef production. A large number of beef cows are raised in solution 26, but few calves are purchased from other states. In solution 27 fewer calves are raised in Iowa, but a large number of calves are imported.

Solution 26 is examined in detail to (a) get an insight into the production potential of the resources on Iowa farms and (b) show how individual farms would be organized under optimal conditions. Comparisons are then made with solution 27.

Microanalysis of Aggregate Solution 26

For solution 26, the price of corn was $1 per bushel, the price of soybeans was $2.35 per bushel, the price of hogs was $10.70 per hundredweight, and the price of choice steers was $17 per hundredweight. The prices that actually existed on the average in 1965 were $1.10-corn, $2.59-soybeans, $20.80-hogs, and $25

Table 4. Actual farm production in 1965 and optimum farm production from selected solutions, Iowa.

Item	Unit	1965 actual	Solution number 26	27	28	37	40
Cattle production							
Beef cows	1,000 head	1,250	2,063	1,428	156	525	592
Calves on feed							
Inshipments	1,000 head	3,000	665	4,617	20,073	0	3,446
Native	1,000 head	1,200[a]	1,630	1,128	123	0	468
Total	1,000 head	4,200	2,295	5,745	20,196	0[b]	3,914
Live beef sold	million lbs.	4,688	2,766	6,310	21,387	89	4,280
Hog production							
Fall farrowings	1,000 litters	1,202[c]	1,325	1,376	0	7,524	6,678
Spring farrowings	1,000 litters	1,458	1,172	885	0	7,994	6,769
Pigs per litter	pigs	7.2	8.0	8.0	0	8.0	8.0
Hogs marketed	1,000 pigs	18,244	19,976	18,088	0	124,154	107,576
Live hogs sold	million lbs.	4,452	4,932	4,468	0	30,650	26,558
Crop production							
Corn harvested	1,000 acres	9,871	11,972	11,941	12,985	17,245	17,406
Corn sales[d]	million cwt.	182	381	289	42	-82	-70
Soybeans harvested	1,000 acres	4,756	6,985	6,960	2,938	1,743	1,481
Oats harvested	1,000 acres	1,971	1,632	1,535	1,768	1,982	1,878
Rotation meadow[e]	1,000 acres	5,600	3,014	3,167	5,912	2,632	2,838

[a]Some are from dairy stock.
[b]All calves are sold rather than fed out.
[c]Born in 1964.
[d]Net corn exports from Iowa.
[e]Cropland used as pasture or harvested as hay. Source of 1965 data: U.S. Department of Agriculture, Consumer and Marketing Service. Livestock and meat statistics, 1965. U.S. Dept. Agr. Stat. Bul. 333. 1966. Iowa Crop and Livestock Reporting Service. Annual farm census, 1965. Iowa Dept. of Agr., Des Moines, Iowa. 1966.

choice steers. There were several reasons that the model showed very low livestock prices associated with near-1965 levels of livestock production. First, the farmers were assumed to have perfect knowledge of production alternatives, prices and technical coefficients. Second, a level of technology more advanced than actually existed on the average farm in Iowa in 1965 was assumed. Third, the farm operator was assumed to maximize profits. Finally, one of the institutional restraints—the feed-grain program—was assumed not to exist.

In the model, 15.5 million acres of class 1 land, 5.9 million acres of class 2 land, and 2.2 million acres of class 3 land could be harvested. The model contained five rotations for the class 1 land.[18] In solution 26, only two were used, continuous corn (4.6 million acres) and corn-soybeans (10.9 million acres), and all the class 2 land was put into three rotations, CCOM (1.3 million acres), CSOM (0.2 million acres), and CSSOMM (4.4 million acres). The class 3 land was divided between the COMM rotation (2.1 million acres) and continuous meadow (0.1 million acres). These rotations gave total crop production of about 12 million acres of corn, 7 million acres of soybeans, 1.6 million acres of oats, and 3 million acres of rotation meadow. Corn silage was an alternative not used on any of the representative farms. Actual crop acreages in 1965 were nearly 9.9 million acres of corn, 4.8 million acres of soybeans, 2 million acres of oats, and 3 million acres of hay. Substantial cropland acreage was also planted in 1965 to other crops or, because of the feed-grain program, left idle. The solution gave state average crop yields of 86.8 bushels of corn, 48.2 bushels of oats, and 32.6 bushels of soybeans per acre. Actual 1965 crop yields per acre were 82, 52, and 26 for corn, oats, and soybeans, respectively.[19]

In solution 26, 1,172,000 spring litters and 1,325,000 fall litters of hogs were farrowed on farms in Iowa, giving a total of 2,497,000 liters. The heavy farrowing months were February (1,141,000 litters) and November (829,000 litters), with fewer farrowings in May and August. In the fall of 1964, Iowa farmers actually farrowed 1,202,000 litters. The spring 1965 farrowings totaled 1,458,000 litters, giving a total of 2,660,000 litters for the year. Total pork produced was about the same in solution 26 as actually occurred in 1965. The average size of litter was greater in the model, but this was offset because the hogs actually marketed in 1965 were carried to heavier weights than were the hogs in the model.

No hog-farrowing or feeding facilities were purchased in solution 26 since the level of production of hogs was not substantially higher than actual hog production on Iowa farms in recent years.

The results show that about 2.3 million beef calves were fattened, with 2.1 million being fed on drylot and 0.2 million being fed exclusively on pasture. About 70 percent (1.6 million) of the calves were raised in Iowa, with the remainder imported. No yearlings were purchased, and no silage was fed to the cows or calves.

The total amount of beef housing and feeding facilities in Iowa was enough to house and feed all the cattle raised, but it was not allocated "efficiently" among the representative farms. The results showed that 141,000 animal units of beef housing were purchased even though 1.7 million animal units of housing were not used.

Solution 26 shows large quantities of unused resources on Iowa farms. The model production of crops, hogs, and beef described was achieved without additional funds being borrowed on any of the representative farms. Only about 45 percent of the cash available on the representative farms was used to pay for farm expenditures. The remainder was invested off the farm.

About 47,000 man-years of operator and family labor also was not used during some period of the year. The 47,000 is an accumulation of the unused portion of the operators' and their families' time. On most of the representative farms there was unused labor during all months except April (fieldwork) and November (hog farrowing and harvesting). In solution 26, 3,064 and 143 man-years of labor were hired in April and November, respectively.

Microanalysis of Aggregate Solution 26

The organization of farm enterprises did not differ greatly from one representative farm to the next at solution 26.[20] The general sequential pattern that emerged in solutions leading to the one that maximized farm income was (a) maximize the row-crop (corn and soybean) acreage, (b) raise enough beef cows to fatten the home-raised beef calves, and (c) increase the hog enterprise until the feeding or farrowing facilities became limited. At the product prices used for solution 26, there were no representative farms specializing entirely in crops, hogs, a beef cow-calf operation, or a cattle-fattening operation. A beef-fattening enterprise and beef cow-calf enterprise were on every representative farm. The largest herd of beef cows was 48 head, and 23 representative farms had beef cow herds of 20 head or less. Hogs were raised on all but two of the 31 representative farms, but only 45 litters were farrowed on the farm with the largest hog enterprise. Less than 20 litters were farrowed on 20 representative farms.

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[18] See the discussion on the alternative uses of the three types of cropland in the subsection, "Cropping Activities" under "Alternative Uses of Farm Resources."

[19] Over the period of this study, the actual level of technology in crop production increased so rapidly that the yields included in the study, though based on an assumption of "advanced technical efficiency," were about the same as actual 1965 yields.

[20] This is not unique to solution 26. In general, the 31 representative farm optimum plans look similar at each of the other 39 aggregate solutions as well.

Area Analysis of Aggregate Solution 26

Solution 26 gave a locational distribution of agricultural production that in some instances, differed substantially from the actual distribution. Both the optimal (solution 26) and the actual distribution of the production of specified farm products among the areas of Iowa are shown in table 5. For ease of comparison, the data are presented in percentage form in table 6.

Several deviations of solution 26 from actual 1965 production patterns are shown in these two tables. In 1965 the distribution of corn acreage among the 10 areas of Iowa was generally proportional to the distribution of cropland among the areas. Soybean acreage, however, was relatively concentrated in areas 1, 3, and 4. Solution 26 had a high density of corn acreage and a very low density of soybean acreage in areas 7 and 8. These two areas account for one-fourth of the state's cropland. In 1965, 20 percent of Iowa's soybean acreage and 27 percent of the corn acreage were planted in areas 7 and 8. But in solution 26, 40 percent of the state's corn acreage and only 5.5 percent of the state's soybean acreage were in these two areas. In areas 7 and 8, the model's corn yield was high relative to its soybean yield.

In 1965, the density of oat acreage was high in areas 4, 7, and 8 and relatively low in areas 2, 5, 6, and 9. Solution 26 had oats concentrated somewhat in areas 3, 6, and 10. These areas have high percentages of class 3 cropland—cropland that could only have continuous meadow or a corn-oats-meadow-meadow rotation. Area 6, an extreme case, had only 5 percent of the state oat acreage in 1965. Solution 26 put 17 percent of the oat acreage in area 6 since 45 percent of the cropland in area 6 was class 3 cropland with a COMM rotation. (One-fourth of the class 3 cropland was in oats.)

Pork production in 1965 was apportioned among areas in about the same manner as cropland. In solution 26, pork production was about 50 percent above the 1965 levels of pork production in areas 1 and 4 and about 50 percent below 1965 levels in areas 3, 6, and 9. The remaining five areas showed little change. In solution 26, hogs were raised on every representative farm in areas 1 and 4, whereas there were actually many cash-grain farms with no livestock in these two areas.

Beef cow density in 1965 was high in areas 3, 4, 5, 6, and 8, and low in areas 1 and 2. In solution 26, beef cow numbers for the state as a whole were twice as high as the 1965 level, but the distribution of beef cows among the 10 areas was approximately the same as in 1965.

In solution 26, most of the fat beef were home-grown calves. Thus, the total production of beef was correlated with the location of the beef cows. As a result, beef production in areas 5, 6, and 10 was greater under the solution 26 than actually held true in 1965. On the other hand, area 4 had less beef production than was true in 1965.

In general, solution 26 showed a shift of beef production to the southern and eastern parts of the state. Hog production was more concentrated in northern and eastern Iowa. The beef price used in solution 26 ($17 per hundredweight) caused beef production to shift to regions where it was advantageous to fatten home-grown beef calves. Areas in southern, northeastern, and southeastern Iowa with large amounts of pasture were thus given a relative advantage in beef production.

Table 5. Optimal farm production (solution 26) and actual farm production in 1965 by geographical areas of Iowa and for the state.

Item	Unit	Area of Iowa										State total
		1	2	3	4	5	6	7	8	9	10	
Optimal												
Corn harvested	1,000 acres	929	406	867	2,840	353	510	2,248	2,570	773	476	11,972
Soybeans harvested	1,000 acres	1,005	374	1,014	2,909	372	396	385	0	422	108	6,985
Oats harvested	1,000 acres	76	118	277	129	101	281	91	172	171	216	1,632
Corn yield	bushels/acre	80	74	72	87	80	67	88	100	87	87	87
Soybeans yield	bushels/acre	32	31	30	33	35	32	32	---	33	35	33
Oat yield	bushels/acre	58	37	40	54	40	42	47	64	53	53	48
Hog sales	million lbs.	645	177	287	1,307	209	164	776	695	251	421	4,932
Live beef sales	million lbs.	451	172	281	314	195	354	237	304	248	211	2,766
Beef cows	1,000 head	91	125	281	193	193	352	132	241	249	206	2,063
Actual—1965												
Corn harvested[a]	1,000 acres	920	468	1,086	2,522	421	585	1,310	1,359	728	472	9,871
Soybeans harvested[a]	1,000 acres	448	221	373	1,833	222	374	546	417	282	40	4,756
Oats harvested[a]	1,000 acres	204	69	183	314	93	99	352	308	127	221	1,971
Corn yield[a]	bushels/acre	74	82	85	80	76	74	82	92	89	80	82
Soybeans yield[a]	bushels/acre	24	25	29	25	26	25	25	31	28	27	26
Oat yield[a]	bushels/acre	57	45	44	58	40	38	56	54	45	54	52
Hog sales[b]	million lbs.	392	165	467	814	223	276	601	699	445	370	4,452
Live beef sales[b,c]	million lbs.	788	272	844	1,059	127	98	333	727	267	173	4,688
Beef cows[a]	1,000 head	54	41	135	166	138	222	101	183	115	95	1,250

[a]Taken from: Iowa Crop and Livestock Reporting Service. Annual farm census, 1965. Iowa Dept. of Agr., Des Moines, Iowa. 1966.

[b]The state total is obtained from: U. S. Department of Agriculture, Consumer and Marketing Service. Livestock and meat statistics, 1965. U. S. Dept. Agr. Stat. Bul. 333. 1966. The division by areas is based upon county production as reported in: Iowa Crop and Livestock Reporting Service. Annual farm census, 1965. Iowa Dept. Agr., Des Moines, Iowa. 1966.

[c]"Beef sales" include dairy animals sold.

Solution 27

For solution 27 (table 7) in comparison with solution 26 (table 5 and 6) number of calves on feed increased 150 percent, and the quantity of beef sold increased 128 percent. On the other hand, beef cow numbers were reduced 30 percent, implying a 600-percent increase in calves shipped into Iowa.

The increase in beef production caused only minor changes in optimal use of cropland. Oat acreage decreased 97,000 acres, and rotation meadow and hay acreage increased 153,000 acres (table 3). Corn and soybean acreage decreased only slightly.

Compared with solution 26, there was a reduction of only 9 percent in pork production in solution 27. However, the distribution of production between spring and fall litters changed considerably. In solution 26, 47 percent of the pigs were born in the spring, as compared with only 39 percent in solution 27. A reallocation of labor and capital to allow increased beef production caused the adjustment in hog enterprises.

Only 45 percent of the aggregate cash restriction and 64 percent of the aggregate total operator and family labor restriction were used in farming activities for solution 26. No funds were borrowed, and only 11 million man-hours of labor were hired. In solution 27, 67 percent of the aggregate cash restriction and 67 percent of the aggregate family labor restriction were used in farming activities. In addition, 11 million dollars were borrowed in period 2 (April to September), and 12 million man-hours of labor were hired in solution 27. Thus, the increase in beef production in solution 27 caused a substantial increase in the use of capital but only a slight increase in labor use.

The geographical distribution of crop production in solution 27 is about the same as for solution 26, but the geographical distribution of livestock production differs considerably. Table 7 shows the production and percentage distribution of production in each of the 10 areas of Iowa for solution 27.

The $1 increase in price of cattle (between solutions 26 and 27) caused considerable shifts in livestock production in areas 4 and 6. In solution 26, area 4 had 26.6 percent of the state's hog sales, 11.5 percent of cattle sales, and 9.3 percent of the total beef cows. In solution 27, however, area 4 had 36 percent of hog sales, 15.7 percent of the cattle sales, and only 3.1 percent of the total beef cows. The higher cattle

Table 6. The percentage of optimal farm production (solution 26) and actual farm production in 1965 in each geographical area of Iowa.

Item	Unit	Area of Iowa 1	2	3	4	5	6	7	8	9	10	State total
Cropland	percent	9.2	4.9	11.5	25.8	4.8	7.4	12.3	12.3	7.2	4.6	100.0
Optimal												
Corn acreage	percent	7.8	3.4	7.2	23.7	2.9	4.3	18.8	21.5	6.4	4.0	100.0
Soybean acreage	percent	14.4	5.4	14.5	41.6	5.3	5.7	5.5	0.0	6.0	1.6	100.0
Oat acreage	percent	4.7	7.2	17.0	7.9	6.2	17.2	5.6	10.5	10.5	13.2	100.0
Hog sales	percent	13.1	3.6	5.8	26.6	4.2	3.3	15.7	14.1	5.1	8.5	100.0
Live beef sales	percent	17.1	6.2	9.9	11.5	6.9	12.5	8.7	10.9	8.8	7.5	100.0
Beef cows	percent	4.4	6.1	13.6	9.3	9.3	17.1	6.4	11.7	12.1	10.0	100.0
Actual—1965												
Corn acreage	percent	9.3	4.7	11.0	25.5	4.3	5.9	13.3	13.8	7.4	4.8	100.0
Soybean acreage	percent	9.4	4.6	7.8	38.6	4.7	7.9	11.5	8.8	5.9	0.8	100.0
Oat acreage	percent	10.4	3.5	9.3	15.9	4.7	5.0	17.9	15.7	6.4	11.2	100.0
Hog sales	percent	8.8	3.7	10.5	18.3	5.0	6.2	13.5	15.7	10.0	8.3	100.0
Live beef sales	percent	16.8	5.8	18.0	22.6	2.7	2.1	7.1	15.5	5.7	3.7	100.0
Beef cows	percent	4.3	3.3	10.8	13.2	11.0	17.8	8.1	14.7	9.2	7.6	100.0

Table 7. Geographical distribution of optimal aggregate production from solution 27.

Item	Unit	Area of Iowa 1	2	3	4	5	6	7	8	9	10	State total
Corn harvested	1,000 acres	926	424	867	2,809	338	510	2,440	2,401	773	453	11,941
Soybeans harvested	1,000 acres	1,000	356	1,014	2,906	372	396	194	168	422	132	6,960
Oats harvested	1,000 acres	74	118	276	98	86	282	91	129	171	210	1,535
Hog sales	million lbs.	644	51	151	1,612	112	124	776	591	114	293	4,468
Live beef sales	million lbs.	701	446	1,075	993	446	396	532	710	507	504	6,310
Beef cows	1,000 head	5	79	181	44	161	372	49	154	224	159	1,428
Percentage distribution												
Corn acreage	percent	7.7	3.6	7.3	23.5	2.8	4.3	20.4	20.1	6.5	3.8	100.0
Soybean acreage	percent	14.4	5.1	14.6	41.7	5.3	5.7	2.8	2.4	6.1	1.9	100.0
Oat acreage	percent	4.8	7.7	18.0	6.4	5.6	18.4	5.9	8.4	11.1	13.7	100.0
Hog sales	percent	14.4	1.1	3.4	36.0	2.5	2.8	17.4	13.2	2.6	6.6	100.0
Live beef sales	percent	11.1	7.1	17.0	15.7	7.1	6.3	8.4	11.3	8.0	8.0	100.0
Beef cows	percent	0.4	5.5	12.7	3.1	11.3	26.1	3.4	10.7	15.7	11.1	100.0
Cropland	percent	9.2	4.9	11.5	25.8	4.8	7.4	12.3	12.3	7.2	4.6	100.0

price under solution 27 caused use of the limited pasture in area 4 (north-central Iowa) for fattening feeder calves rather than for keeping beef cows. The shift from beef cows to feeders also enabled the hog enterprise to increase. Thus, hog production actually increased in area 4 as the price of beef was increased by $1 from solution 26 to solution 27.

In area 6 (southern Iowa), where a large percentage of the cropland is used for forage, the response to a $1 increase in the cattle price differed greatly from that of area 4. In solution 26, area 6 accounted for 3.3, 12.5, and 17.1 percent of the state's hog sales, cattle sales, and beef cow numbers, respectively. But in solution 27, the corresponding percentages were 2.8, 6.3, and 26.1. Abundant forage in area 6 enabled an expansion of the cow herds for greater beef calf production. All the calves were fattened within the area. Thus, both total cow numbers and total cattle sales increased only slightly in area 6 in response to the $1 increase in cattle price. However, for the state as a whole, cattle sales increased 138 percent, and beef cow numbers decreased 31 percent.

ANALYSIS OF THE SOLUTIONS THAT HAVE THE GREATEST LIVESTOCK PRODUCTION

The potential of Iowa agriculture also can be examined from the standpoint of those optimal solutions showing the use of most of the state's farm resources in optimal production. Solution 28 emphasizes Iowa's potential for beef cattle production, and solution 37 emphasizes the potential for hog production. The highest of the alternative cattle prices ($24) is used in solution 28, and the highest of the alternative hog prices ($15) is used, in solution 37. Solution 40, which has both $24-cattle and $15-hogs, is also examined.

Solution 28: Largest Beef Cattle Production[21]

A summary of both the Iowa production obtained from solution 28 and actual production in Iowa in 1965 is shown in table 4. Optimally, there would be specialization in the production of beef on Iowa farms at the prices used in solution 28. Solution 28 shows that, if Iowa farmers could purchase feeder calves for $25.13 per hundredweight, sell the fattened cattle for $24 per hundredweight and follow all the other conditions of the model, they could profitably fatten nearly 20.2 million head of feeder cattle—equivalent to nearly half of the nation's beef consumption in 1965.

No hogs are raised in Iowa under solution 28, and beef cow numbers are only 12 percent as great as in 1965. The production of crops is also consistent with specialization in beef. Of the 40 solutions considered, solutions 28 and 32 have the largest acreage of rotation meadow, 5.9 million acres, and the smallest acreage of row crops. ,

The model assumptions and limitations should be kept in mind when the results from solution 28 are used.[22] For example, the model contains no detailed analysis of the factor-input markets. Such inputs as commercial feed and feeder cattle are assumed available to Iowa farmers in unlimited quantities at a given price. Solution 28 shows that 20 million head of feeder cattle would be imported into Iowa at a feeder cattle price of $25.13. Therefore, the results are interpreted as follows: If Iowa farmers could obtain 20 million head of feeder cattle from other states at a price of $25.13 per hundredweight and if the other previously discussed assumptions of the model are true, then there are adequate resources currently on Iowa farms to produce 21 billion pounds of live beef.

Most of the resources on Iowa farms were utilized in the production of farm products in solution 28. No off-farm investments were made, and large quantities of funds were borrowed on each of the representative farms. In all, 1.35 billion dollars was borrowed for the whole year, and an additional 0.45 billion dollars was borrowed for the second half of the year in solution 28. However, additional funds could have been borrowed on all but two of the 31 representative farms.

The utilization of Iowa farm labor in solution 28 is shown in table 8. During April, June, and November, virtually all the available family labor is utilized. Large quantities of hired labor are also used during these three months.[23] The labor needs for fattening beef cattle are relatively uniform throughout the year,

[21] Solution 32 is identical to solution 28.

[22] A discussion of the limitations of this model is contained in Sharples, Miller, and Day (16).

[23] Table 8 shows that labor is hired in a given month even though all the operator and family labor are not used in that month. The reason is that, on some representative farms, there is excess labor, but on others, labor is hired.

Table 8. Aggregate labor use in Iowa during selected months for solutions 28 and 37.

	Available operator and family labor[b]	Operator and family labor used[b]	Hired labor	Total used[b]
	(1,000 man-hours)			
Solution 28				
February	28,160	13,766	7	13,773
March	31,927	18,810	0	18,810
April	31,927	30,114	10,820	40,934
May	38,335	33,959	1,141	35,100
June	43,618	42,128	10,287	52,415
July	43,618	39,804	3,709	43,513
September	35,693	17,263	16	17,279
October	35,693	19,392	85	19,477
November	31,927	29,550	6,418	35,968
Solution 37				
February	28,160	24,222	1,078	25,300
March	31,927	19,689	0	19,689
April	31,927	24,040	16,037	40,077
May	38,335	25,539	6,521	32,060
June	43,618	27,367	0	27,367
July	43,618	28,634	1,035	29,669
September	35,693	17,531	0	17,531
October	35,693	31,260	5,044	36,304
November	31,927	30,842	19,454	50,296

[a] The months of January, August, and December were not included in the linear-programming analysis because they were not considered potential labor-shortage months.

[b] These figures do not include a quantity of overhead labor subtracted, for overhead purposes, from the labor resources of each representative farm before the linear-programming solutions were obtained.

but labor peaks are caused by the crop enterprises. In solution 28, large quantities of labor are needed in April and May for field work; labor for haying is needed in June and July, and labor for harvesting corn is needed in November. Because of the labor peaks, farm labor must be hired on the representative farms even though the annual supply of operator and family labor is not fully utilized.

In the linear programming model, the maximum amount of hired labor allowed each representative farm per year was 20 percent above the actual amount used in 1959. But no monthly limitations were placed upon hired labor. Thus, the total quantity of labor hired during the year in solution 28 is only 50 percent of the maximum allowable, but labor hiring is concentrated in five months—April through July and November (see table 8). If each hired worker were to work full-time during the month (208 hours), then 52,000 laborers would be needed in April in solution 28. Likewise, 50,000, 18,000, and 31,000 workers would be hired in June, July, and November, respectively. The actual numbers of hired workers in April, June, July, and November 1964, were 22,000, 67,000, 89,000, and 24,000, respectively. Of course, the actual number of hours worked per hired laborer each month in 1964 was probably considerably below 208 hours.

Microanalysis of Solution 28

Beef calves are fattened on all 31 representative farms. The number of calves fattened per representative farm varies from 36 head to 259 head. Beef cows are raised on one-third of the representative farms, but the largest herd is only 17 cows, and the average herd is only 6 head.

On all but the three representative farms in area 8, the total production of corn, pasture, and hay is fed to cattle. Some corn is sold on the three representative farms in area 8. But it would have been possible (though not profitable under the price set for this solution) to have increased feed production on 22 of the representative farms, with fewer acres allocated to soybeans and more acres to corn and meadow. Thus, the home-grown cattle feed supply in Iowa in solution 28 was not the maximum possible.

Area Analysis of Solution 28

The area distribution of production obtained from solution 28 is shown in table 9, and the percentage distribution of production by areas is shown in table 10. Corn production is distributed over Iowa about the same as the actual distribution of production in 1965, as shown in table 6. However, in the area 4--north-central Iowa--the percentage of corn grown is somewhat lower than in 1965 and the percentage of soybeans and oats grown is substantially higher than in 1965. In solution 28, no soybeans are grown in areas 6, 8, and 10. The distribution of beef cattle production is about the same as the distribution of corn production. Most of the beef cows are raised in area 6, southern Iowa, where pasture is abundant.

Solution 37: Larger Hog Production

In solution 37, hog production is 6.9 times the 1965 level in Iowa, or 1.7 times the U.S. hog production level in 1965. The price levels for hogs, beef cattle and soybeans used in this solution are $15, $24, and $2.35, respectively.

In contrast to solution 28, most of the Iowa farm resources are invested in hog production, and no resources are used for fattening beef cattle. However, 525,000 beef cows are raised to utilize the pasture not used by hogs. All the beef calves are sold outside Iowa.

Table 9. Geographical distribution of optimal production from solutions 28, 37 and 40.

Item	Unit	Area of Iowa 1	2	3	4	5	6	7	8	9	10	State total
Solution 28												
Corn harvested	1,000 acres	1,350	651	1,552	2,516	611	882	1,722	2,186	936	579	12,985
Soybeans harvested	1,000 acres	250	71	218	1,942	63	0	216	0	178	0	2,938
Oats harvested	1,000 acres	53	77	239	482	69	299	211	20	107	211	1,768
Hog sales	million lbs.	0	0	0	0	0	0	0	0	0	0	0
Live beef sales	million lbs.	2,171	1,022	2,329	4,624	1,053	1,372	2,755	3,213	1,722	1,126	21,387
Beef cows	1,000 head	0	19	9	0	11	87	0	0	0	30	156
Solution 37												
Corn harvested	1,000 acres	1,729	729	1,881	4,597	751	906	2,408	2,464	1,195	585	17,245
Soybeans harvested	1,000 acres	205	55	0	1,151	0	0	226	106	0	0	1,743
Oats harvested	1,000 acres	94	139	380	162	157	322	116	172	224	216	1,982
Hog sales	million lbs.	2,731	1,208	3,061	7,637	1,511	1,610	4,126	4,807	2,377	1,582	30,650
Live beef sales	million lbs.	0	6	8	0	6	43	0	0	9	17	89
Beef cows	1,000 head	0	31	46	0	38	259	0	0	50	101	525
Solution 40												
Corn harvested	1,000 acres	1,745	729	1,881	4,697	751	906	2,439	2,478	1,195	585	17,406
Soybeans harvested	1,000 acres	190	55	0	949	0	0	195	92	0	0	1,481
Oats harvested	1,000 acres	94	139	381	80	157	324	114	149	224	216	1,878
Hog sales	million lbs.	2,450	880	2,359	6,880	1,176	1,413	3,852	4,405	1,934	1,209	26,558
Live beef sales	million lbs.	320	354	668	942	332	278	279	426	338	343	4,280
Beef cows	1,000 head	2	23	55	0	37	276	7	2	87	103	592

In table 4, the 89 million pounds of beef sold in solution 37 is cull-cow beef.

The change in livestock prices from solution 28 to 37 caused a big change in the cropping systems. Table 4 shows 4.26 million more acres of corn in solution 37 than in solution 28, but soybean and rotation meadow acreages are reduced. In solution 37, the rowcrop (corn and soybean) acreage is maximized.

Only a small increase in hog production is possible with hog prices higher than $15 because, at $15, most of the available labor and capital is invested in hog production and crops providing hog feed. Capital and (or) labor are completely used on 25 of the 31 representative farms. There is very little excess capital or labor on the remaining representative farms. In solution 37, only 57 million dollars, out of a total of 2,362 million, of working capital is invested off the farm.

The distribution of labor use for solution 37 is shown in table 8. Labor peaks come in Febrary, April through July, and October and November. Hog farrowing contributes to labor peaks in February, May, and November. Crop planting and harvesting contribute to labor peaks in the spring and fall. Large quantities of labor are hired in April, May, October, and November. In November, an equivalent to 93,500 full-time laborers are hired. In 1964 only 24,000 hired laborers worked on Iowa farms and most of these were employed less than full time.[24] Because of the less-uniform distribution of labor requirements throughout the year for hog production relative to beef production, solution 37 uses slightly less total family labor than solution 28, but more labor is hired.

[24] For further discussion of the hired labor restrictions, see the chapter on evaluation of methods in Sharples (15).

Microanalysis of Solution 37

Hogs are raised on every representative farm for solution 37, with the size of the hog enterprise ranging from 37 litters per year to 193 litters per year. The typical size is 80 litters.

Beef cows are raised on 14 representative farms, with the typical herd size being 10 head. These 14 representative farms have relatively more pasture than the other representative farms. No calves are kept for fattening because it is more profitable to use the homegrown feed for hog fattening.

The hog price, $15, is high enough to make the purchase of corn profitable on 19 representative farms. On the remaining 12 representative farms, all corn is fed, but no corn is purchased.

Area Analysis of Solution 37

Tables 9 and 10 show that the distribution of hog production among the 10 areas in solution 37 is about the same as the distribution of corn acreage. Thus, hog production is concentrated in the areas with the most productive corn land--areas 4, 7, and 8. In solution 37 relative to solution 28, the corn acreage is more concentrated in area 4 and less concentrated in most of the other areas. In area 4, the corn acreage is increased 83 percent over the area 4 corn acreage shown in solution 28. The increase in corn acreage is accompanied by a corresponding reduction in soybean, oat and meadow acreage in area 4. The location of the beef cow herds is in those areas with an abundance of pasture–areas 2, 3, 5, 6, 9, and 10.

Solution 40

To visualize what happens in the model when both

Table 10. The percentage of optimal crop acreage and livestock production in each geographical area of Iowa for solutions 28, 37 and 40.

Item	Unit	Area of Iowa 1	2	3	4	5	6	7	8	9	10	State total
Solution 28												
Corn acreage	percent	10.4	5.0	11.9	19.4	4.7	6.8	13.3	16.8	7.2	4.5	100.0
Soybean acreage	percent	8.5	2.4	7.4	66.1	2.1	0.0	7.4	0.0	6.1	0.0	100.0
Oat acreage	percent	3.0	4.4	13.5	27.3	3.9	16.9	11.9	1.1	6.1	11.9	100.0
Hog sales	percent	---	---	---	---	---	---	---	---	---	---	----
Live beef sales	percent	10.1	4.8	10.9	21.6	4.9	6.4	12.9	15.0	8.1	5.3	100.0
Beef cows	percent	0.0	12.2	5.8	0.0	7.0	55.8	0.0	0.0	0.0	19.2	100.0
Solution 37												
Corn acreage	percent	10.0	4.2	10.9	26.7	4.4	5.2	14.0	14.3	6.9	3.4	100.0
Soybean acreage	percent	11.8	3.2	0.0	66.0	0.0	0.0	13.0	6.1	0.0	0.0	100.0
Oat acreage	percent	4.7	7.0	19.2	8.2	7.9	16.2	5.9	8.7	11.3	10.9	100.0
Hog sales	percent	8.9	3.9	10.0	24.9	4.9	5.3	13.5	15.7	7.7	5.2	100.0
Live beef sales	percent	0.0	6.7	9.0	0.0	6.7	48.4	0.0	0.0	10.1	19.1	100.0
Beef cows	percent	0.0	5.9	8.8	0.0	7.2	49.3	0.0	0.0	9.5	19.2	100.0
Solution 40												
Corn acreage	percent	10.0	4.2	10.8	27.0	4.3	5.2	14.0	14.2	6.9	3.4	100.0
Soybean acreage	percent	12.8	3.7	0.0	64.1	0.0	0.0	13.2	6.2	0.0	0.0	100.0
Oat acreage	percent	5.0	7.4	20.3	4.3	8.4	17.2	6.1	7.9	11.9	11.5	100.0
Hog sales	percent	9.2	3.3	8.9	25.9	4.4	5.3	14.5	16.6	7.3	4.6	100.0
Live beef sales	percent	7.5	8.3	15.6	22.0	7.7	6.5	6.5	10.0	7.9	8.0	100.0
Beef cows	percent	0.3	3.9	9.3	0.0	6.3	46.6	1.2	0.3	14.7	17.4	100.0

$15-hogs and $24-cattle are used, solution 40 is presented. Generally, hog production still predominates, but fattening of beef cattle takes places at a level about equal to 1965 beef cattle production in Iowa. The aggregate crop acres are about the same as in solution 37.

The aggregate labor and capital resource use patterns are similar to those discussed for solution 37. But in solution 40, about 12 percent more capital and 1 percent more labor are used than in solution 37. The beef cattle-feeding enterprises are capital intensive relative to the hog enterprises because of the purchase of a feeder calf.

Microanalysis of Solution 40

Hogs are raised on all 31 representative farms. Typically, about 80 litters were farrowed a year on the representative farms, but about 200 litters were farrowed on one representative farm. The total number of spring and fall litters was about the same. Additional farrowing and feeding facilities were purchased on many farms.

Beef cattle were fattened on all but 2 of the 31 representative farms. A total of 3.9 million head of beef calves were fattened in the state as a whole, 3.4 million head were imported from other states, and 500,000 were home raised. Beef calves were purchased on 14 of the 31 representative farms. The typical number purchased was about 40, but one representative farm purchased 125 head. Sixteen representative farms had beef cows, but most had less than 10 head.

Labor and (or) capital limited production on all but four of the 31 representative farms. Capital was the only limiting resource on 17 farms. Labor limited production on 10 of the representative farms, but on 6 of these 10, all sources of capital were also exhausted.

Area Analysis of Solution 40

The area distribution of crops, hogs, and beef cows in solution 40 is similar to that of solution 37. Since beef cattle can use both pasture and corn and since hogs use mostly corn, the relative density of beef cattle is less in the areas with the most corn, whereas hog density is the highest in the same areas.

Effects of Optimal Production Practices on Aggregate Farm Income in Iowa

One of the objectives of this study was to show the effect of optimal production practices on aggregate farm income in Iowa. Heady (9, page 819) states the theoretical relationships concisely: "The manner in which the net returns are affected by specific technological improvements depends . . . upon the price elasticity of demand for the specific product and the effect of the innovation on (a) the total output, (b) the total costs of production, and (c) the nature of the short-run supply function for individual factors of production." The difference between the model conditions and the real world conditions can be viewed generally as technological improvements, whether they are increases in pigs per litter, rates of gain or technological improvements in managerial ability to gain perfect knowledge and maximize profits. Calling improvements in managerial ability a technological improvement is somewhat unconventional, but it is a useful concept in this discussion.

The effect of the technological improvements incorporated in the model upon Iowa agriculture was examined under four situations. In all situations, the short-run supply function for the factors of production was assumed perfectly elastic. The product demand conditions, however, were varied over the four situations.

SITUATION I

In situation 1, the demand curve for Iowa farm products was assumed located such that solution 27 was in equilibrium.[25] This assumption implies that, with the beef cattle price at $18 per hundredweight, the demand for Iowa beef would increase 35 percent over what it was in 1965 and that, at a hog price of $10.70, the hog demand would be about the same as in 1965. If, under the conditions of situation 1, Iowa farmers were to incorporate the technological improvements of the model, they would find that their total costs would be reduced 17 percent from 1965 levels but their gross income also would be reduced, resulting in a reduction of 25 percent in profits (table 11). Because of the increase in production potential and because of the assumed inelastic demand for farm products, farmers would be worse off—their incomes would be lowered—by the technological change. The net effect of the technological change would be to lower costs, slightly increase output, and lower profits.[26]

If it were possible for Iowa farmers to incorporate these technological changes and still sell their products at 1965 prices, the effect on profits would be different. For example, if the production from solution 27 (which is near actual 1965 levels of production) could be sold at 1965 prices, profit would be $1,556 million or 66 percent *above* the 1965 level. The problem is that, at 1965 prices, given technological changes assumed in the model, it would be profitable for each farmer *individually* to expand output beyond 1965 levels. But if every farmer expanded output, all farmers would end up with less profit than they had in 1965.

SITUATION II

In situation II, the demand for hogs and beef cattle was assumed such that solution 28 was in equili-

[25] Solution 27 is shown in tables 3, 4, and 11.

[26] Costs are lowered for two reasons: (a) technological efficiency and (b) lower costs of feeder calves. The former is seen in table 12, solution 27, in the expenditures for hired labor and feed. In solution 27, feeder calves are purchased for $19.13 per hundredweight.

brium. In solution 28, the prices of hogs and cattle were $10.70 and $24, respectively. These demand conditions imply a strong consumer preference for beef over pork. The change in the demand assumption, given the technological changes built into the model, would enable Iowa farmers to have higher incomes than in either 1965 or solution 27. Table 11 shows that, compared with solution 27, both receipts and costs doubled in solution 28. Thus, the receipts per dollar of expenditures were about the same in both solutions.

In solution 28, most farm receipts come from sale of fat cattle. Likewise, 54 percent of the expenditures are for purchasing feeder calves. Costs are higher in solution 28 than in any of the other 39 solutions because the major component is the purchase of feeder calves.

SITUATION III

The demand conditions in situation III were assumed such that solution 37 was in equilibrium, reflecting a strong consumer preference for pork relative to beef. Hog and cattle prices are $15 and $16, respectively, for solution 37. Given these demand conditions, the technological changes assumed in the model would enable Iowa farmers to increase their profits from 940 million dollars in 1965 to 1,745 million dollars. Receipts would come mostly from hogs. Feed costs would be the major component of expenditures. Solution 37 gives the highest return per dollar of expenditures of any of the 40 solutions.

SITUATION IV

The demand conditions in situation IV were assumed such that solution 40 was in equilibrium. Of the 40 price combinations considered, the prices of hogs and beef used in solution 40 were closest to historical price levels in Iowa. Table 11 shows that, in solution 40, revenue is 54 percent higher, expenditures are 38 percent higher, and profits are 95 percent higher than in 1965. In solution 40, receipts are high because of the volume of hog sales, and costs are high because of purchased feed.

In the analysis of the four situations, input supply was assumed perfectly elastic, and product demand was shifted. Thus, the four situations point out that the technological changes incorporated in the model could cause aggregate farm income in Iowa to either increase or decrease from 1965 levels, depending upon the product-demand conditions. In the late 1960's product-demand conditions will probably approximate situation I closer than any of the other three situations. Thus, as the level of technology on Iowa farms approaches the level incorporated in the model, aggregate profits could be expected to fall if large increases in output occurred under declining and inelastic demands.

Of course, average farm profit depends, not only on the level of aggregate farm profit, but also on the number of farms in Iowa. A decrease in farm numbers could cause average farm profit in Iowa to increase even though the aggregate level of farm was decreasing. The effect of a decrease in farm numbers in Iowa is covered in the next section.

Aggregate Effect of Farm Size Adjustments on Optimal Production and Resource Use

One objective of this study was to estimate the aggre-

Table 11. Actual farm receipts and expenditures in Iowa in 1965 and receipts and expenditures from aggregate solutions 27, 28, 37, and 40.

Item	1965 actual[a]	Solution number 27	28	37	40
			$1,000		
Farm receipts:					
Cattle	1,059,631	1,114,965	5,129,856	37,745	1,015,677
Hogs	917,103	463,509	0	4,457,895	3,862,729
Corn and oats	364,571	517,097	75,377	0	0
Soybeans	295,879	532,953	229,264	136,019	114,434
Government payments on crops	228,026	0	0	0	0
Other livestock	333,794	0	0	0	0
Miscellaneous	39,306	0	0	0	0
TOTAL	3,238,310	2,628,524	4,434,497	4,631,659	4,992,840
Farm expenditures:					
Feed	529,200	227,592[b]	289,561[b]	1,179,896	1,011,101
Livestock purchased	459,600	388,587[c]	2,219,450[c]	0	381,823[c]
Seed	40,000	66,156	60,621	64,789	63,767
Fertilizer	119,300	138,609	142,171	184,086	185,884
Repairs and miscellaneous	409,300	403,209	616,616	668,274	739,696
Hired labor	68,300	17,298	48,725	73,755	75,779
Fixed costs	672,800	677,242[d]	738,689[d]	716,066[d]	706,570[d]
TOTAL	2,298,600	1,918,693	4,115,833	2,886,806	3,164,620
Profit	939,710	709,831	1,318,664	1,744,853	1,828,220
Receipts per dollar of expenditures	1.41	1.37	1.32	1.60	1.58

[a]Source of 1965 data: U.S. Department of Agriculture, Economic Research Service. Farm Income. 1965 Supplement to FIS 203. 1966.
[b]Grain is not bought on any representative farm.
[c]Beef calves are the only livestock purchased that are not breeding stock.
[d]Actual 1965 fixed cost plus "fixed cost" of added facilities.

gate effect of the trend in farm size on optimal production and resource use. To accomplish this, the extreme case was examined where the largest representative farm in each of the 10 areas was assumed representative of all farms in the area.

The revised aggregation coefficients associated with these 10 representative farms are presented in table 12. The aggregation coefficients were computed by dividing the cropland in a given area by the acres of cropland on the large representative farm in that area. Thus, except for rounding error, the total cropland is the same for the original model as for the revised model. In the original model, the sum of the aggregation coefficients, the assumed number of commerical farms in Iowa, was 141,141. In the revised model the number was reduced to 86,092.

The total quantities of resources on farms in Iowa for both the original (31-farm) and revised (10-farm) models are presented in table 13. Cropland is nearly the same in both models. Total farrowing facilities, total hog-feeding facilities, beef housing, and total beef-feeding facilities are reduced in the revised model, but specific types of facilities, such as confinement hog-feeding facilities and highly mechanized beef feeding are increased in the revised model over the original model. Table 13 also shows that the aggregate supply of capital is reduced slightly in the revised model. But the greatest effect on the change in farm size and farm numbers is to reduce the total quantity of operator and family labor on farms in Iowa. Hired labor, however, is greater in the revised model than in the original model.

The optimal farm plans are the same for the 10 representative farms in the revised model as they are in the original model. Only the aggregation coefficients are changed.

A comparison of the 40 solutions for the revised model and the 40 solutions for the original model reveals that are few significant differences.[27] Thus, the conclusion from this model is that the aggregate effect of the trend in farm size on *optimal* production and resource allocation is small. There are, however, some differences between the results of the original model and the revised model.

Hog production was reduced on all 40 solutions of the revised model relative in the original 40 solutions. The main cause of the reduction in hog production was a shortage of labor on the large representative farms relative to the other representative farms. For example, in the solution 37 (the solution with the greatest hog production), the upper limits of operator, family, and hired labor were reached on 5 of the 10 large representative farms. On the remaining five, operator and family labor were comletely used, and hired labor approached the upper limit. The problem of hiring large quantities of labor in several labor-peak months is more severe in the revised model than in the original model. In solution 37 of the revised model, 71,000 man-months of labor are hired in both April and May and 107,000 man-months are hired in November, whereas in 6 other months no labor is hired.

The major difference between the results of the two models is the revenue per farm. The revision in the

[27] A table showing all 40 solutions to the revised model is presented on pages 111 to 120 of Sharples (15).

Table 12. Revised aggregation coefficients by representative farms.

Area and farm number	Aggregation coefficient	Area and farm number	Aggregation coefficient
Area 1		Area 6	
Farm 1	0	Farm 17	0
Farm 2	0	Farm 18	0
Farm 3	7,673	Farm 19	8,215
Area 2		Area 7	
Farm 4	0	Farm 20	0
Farm 5	0	Farm 21	0
Farm 6	0	Farm 22	10,165
Farm 7	2,435		
Area 3		Area 8	
Farm 8	0	Farm 23	0
Farm 9	0	Farm 24	0
Farm 10	8,908	Farm 25	11,467
Area 4		Area 9	
Farm 11	0	Farm 26	0
Farm 12	0	Farm 27	0
Farm 13	21,249	Farm 28	6,467
Area 5		Area 10	
Farm 14	0	Farm 29	0
Farm 15	0	Farm 30	0
Farm 16	4,623	Farm 31	4,890
Total			86,092

Table 13. Estimates of the sum of all resources available on farms in Iowa based on the aggregation coefficients used in the original model and the revised model.

Item	Unit	Estimate of total resources on all farms in Iowa: Original model	Revised model
Land			
Class 3 cropland	acres	2,188,315	2,188,606
Class 2 cropland	acres	5,946,756	5,949,115
Class 1 cropland	acres	15,468,009	15,465,497
Permanent pasture	acres	4,117,047	4,211,327
Livestock facilities			
Central hog farrowing	sows	2,020,260	1,621,944
Portable hog farrowing	sows	952,181	861,279
Confinement hog feeding	pigs	6,917,087	8,983,984
Portable hog feeding	pigs	19,073,118	13,549,510
Beef housing	animal units	5,120,989	4,958,651
Beef feeding, low mech.	head	4,598,764	606,140
Beef feeding, high mech.	head	6,113,800	9,814,821
Capital			
Cash	1,000 dollars	2,361,985	2,036,370
Chattel mortgage credit	1,000 dollars	568,498	451,099
Operator and family labor			
Annual	man-hours	326,001,430	216,294,320
February	man-hours	28,160,373	19,085,616
March	man-hours	31,926,668	21,668,384
April	man-hours	31,926,668	21,668,384
May	man-hours	38,334,788	26,403,424
June	man-hours	43,618,438	30,708,016
July	man-hours	43,618,438	30,708,016
September	man-hours	35,692,963	24,251,120
October	man-hours	35,692,963	24,251,120
November	man-hours	31,926,668	21,668,384
Hired labor limit	man-hours	64,420,868	93,292,080

model had very little effect on aggregate profit from farming, but the revision reduced farm numbers from 141,141 to 86,092. Thus, the profit per farm was considerably higher for each of the 40 solutions after the revision.

AGGREGATE (STATEWIDE) RESULTS ASSUMING AVERAGE TECHNICAL EFFICIENCY

The preceding results show the great production potential that currently exists on Iowa farms. The purpose of this section is to explore some of the main reasons that Iowa's agricultural production potential is so far beyond current levels of production. To do this, the farmer's management skills need to be broken down into two components.

One component of his management skills is the ability to maximize physical output from a given physical input by a given production process. Examples are the number of pigs per litter that a farmer obtains from a 1-litter system with the sows farrowed in portable housing, or the pounds of feeds needed per pound of gain for yearling beef steers fed in drylot. This component of the management skills is labeled "technical efficiency."

A second component of a farmer's management skills is his ability to combine production *processes* in a way to maximize profit. There are many ways (or processes) to grow hogs, fatten beef cattle, or raise crops. Some combinations of these processes are more profitable than others for a farmer with a given bundle of resources. The component of a farmer's management skill that enables him to accurately choose the more profitable alternatives is labeled "allocative efficiency."

When a linear-programming model is prepared to simulate an individual farmer's management process, the farm's technical efficiency is built into the coefficient matrix. The assumptions are made, when the linear-programming model is solved, that (a) the farmer's technical efficiency is held constant at a specified level and (b) his allocative efficiency is perfect; i.e., he has perfect ability to allocate his resources among the various processes to maximize profits.

To evaluate the effect of "technical efficiency" and "allocative efficiency" on Iowa's production potential in agriculture, the model used in the previous sections of this report was altered: Average technical efficiency was subsituted for advanced technical efficiency. "Average technical efficiency" is defined as the level of technical efficienecy that existed, on the average, on farms in Iowa during 1957-1961. "Advanced technical efficiency" was defined as the best of the commerically acceptable farming techniques known in 1961.

The difference between the results of the average-technical-efficiency model and the results of the advanced-technical-efficiency model can be attributed to the change in the level of technical efficiency. And the difference between actual farm production in Iowa and the average-technical-efficiency results can be attributed to perfect allocative efficiency.

The activities used in the average-technical-efficiency model differ from the advanced-technical-efficiency model because some of the profitable alternatives used by the best farmers are not profitable alternatives for many other farmers. For example, multiple-farrowing systems might be too risky for many farmers. Skillful farmers, however, could operate a highly profitable multiple-farrowing system.

A complete description of the activities and production coefficients for the average-technical-efficiency model is outlined by Sherif (17).

The same representative farms and aggregation coefficients were used in both the average-and advanced-technical-efficiency models. The prices of all factors and most products were also the same. In the average-technical-efficiency model, the corn and soybean prices remained at $1 and $2, respectively, but the hog prices ranged from $11.50 to $14, and the beef cattle prices ranged from $20 to $26. These specific hog and cattle prices, in contrast to the full range of prices incorporated in the previous model, were used to give aggregate quantities of hogs and cattle near historical levels. If lower prices of hogs and cattle had been used, no livestock would have been produced, and if higher prices have been used, aggregate livestock production levels would have been outside the "resonable" range for this particular model.

Optimal solutions were obtained at 26 combinations of hog and cattle prices for each representative farm. The opitmal solutions were aggregated to give state totals in the same manner as in the advanced-technical-efficiency model. The aggregate results for each of the 26 price combinations of hogs and cattle are presented in table 14.

Several comparisons can be made between the results in table 14 for the average-technical-efficiency model and those in table 3 (advanced-technical-efficiency model). The most obvious difference is that, with the advanced-technical-efficiency model, considerably more hogs and cattle can be raised profitably at a given set of prices.

Since the total cropland restraint was nearly the same in both models, the total combined acres of corn, soybeans, oats, and meadow was the same, but more soybeans and less corn generally were raised in the average-technical-efficiency model than in the advanced-technical-efficiency model. In the advanced-technical model, a maximum of 836,000 acres of soybeans were raised at $1-corn and $2-soybeans, but in the average-technical-efficiency model, up to 5.6 million acres were raised at the same corn and soybean prices. Soybeans had a relative advantage for two reasons. First, since fewer livestock were raised in the average-technical-efficiency model, the demand for home-grown feed was less. And second, the corn yield increased relatively more than the soybean yield by going from the average- to the advanced-technical-efficiency assumption because of a considerable increase in the application of fertilizer on corn.

The effect on the results of the change in the technical efficiency assumption is analyzed in two ways. First, the aggregate production and resource use is analyzed for both models at one set of prices. Second, comparisons are made between the aggregate hog and cattle supply functions from the two models.

COMPARISON OF PRODUCTION AT $13-HOGS AND $24-CATTLE UNDER TWO LEVELS OF TECHNICAL EFFICIENCY

Because of the particular hog and cattle price combinations studied in each of the two models, there were only three price combinations common to the two models; $11.50-hogs and $20-cattle, $12-hogs and $20-cattle, and $13-hogs and $20-cattle. This last price

Table 14. Optimum aggregate farm production and resource use in Iowa under the average-technical efficiency model.

Item	Unit	Solution number				
		1	2	3	4	5
Prices						
Hogs	dollars/cwt.	11.50	11.50	11.50	11.50	12.00
Cattle	dollars/cwt.	20.00	21.00	22.00	23.00	20.00
Crops						
Corn	1,000 acres	12,195	12,195	12,160	12,439	12,195
Soybeans	1,000 acres	5,585	5,585	5,620	5,226	5,585
Oats	1,000 acres	2,493	2,493	2,458	2,417	2,493
Rotation meadow	1,000 acres	3,131	3,131	3,167	3,323	3,131
Beef						
Cows	1,000 head	1,268	1,338	200	181	1,114
Calves sold	1,000 head	0	0	0	0	0
Calves purchased	1,000 head	0	4	5,090	7,036	0
Total live beef sold	million lbs.	1,087	1,150	5,415	7,402	955
Hogs						
Total live hogs sold	million lbs.	0	0	0	0	3,413
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	0	0	0	0
Beef housing	1,000 a.u.[a]	0	0	0	794	0
Beef feeding	1,000 head	0	0	0	156	0
Resources						
Borrowed funds	million dol.	0	0	0	10	0
Cash invested off farm	million dol.	1,793	1,777	1,318	966	1,706
Labor hired	million m.h.[b]	4	4	4	5	5
Operator and family labor not used	million m.h.	185	183	168	151	140
Revenue	million dol.	1,000	1,011	1,036	1,081	1,028

[a] Animal units.
[b] Man-hours.

Item	Unit	Solution number				
		6	7	8	9	10
Prices						
Hogs	dollars/cwt.	12.00	12.00	12.00	12.00	12.00
Cattle	dollars/cwt.	21.00	22.00	23.00	24.00	26.00
Crops						
Corn	1,000 acres	12,195	12,199	12,437	12,422	13,831
Soybeans	1,000 acres	5,585	5,582	5,224	4,813	2,421
Oats	1,000 acres	2,493	2,493	2,417	2,357	2,753
Rotation meadow	1,000 acres	3,131	3,131	3,326	3,812	4,400
Beef						
Cows	1,000 head	1,175	200	181	213	196
Calves sold	1,000 head	0	0	0	0	0
Calves purchased	1,000 head	0	4,310	6,832	9,446	12,449
Total live beef sold	million lbs.	1,007	4,610	7,192	9,912	12,991
Hogs						
Total live hogs sold	million lbs.	3,342	3,022	1,730	809	77
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	0	0	0	0
Beef housing	1,000 a.u.	0	0	686	1,878	3,745
Beef feeding	1,000 head	0	0	156	850	2,676
Resources						
Borrowed funds	million dol.	0	0	10	15	294
Cash invested off farm	million dol.	1,694	1,319	941	457	53
Labor hired	million m.h.	6	5	6	8	11
Operator and family labor not used	million m.h.	139	133	128	113	89
Revenue	million dol.	1,037	1,056	1,094	1,150	1,291

combination, solution 17 in table 14 and solution 24 in table 3, is analyzed in detail. These solutions are also indicated with an "a" in figs. 2 and 3.

At $13-hogs and $20-cattle, the more efficient farming practices built into the advanced-technical-efficiency model encourage 3.3 times more hogs and 3.6 times more cattle to be raised than in the average-technical-efficiency model. The increase in livestock also causes corn to be more profitable relative to the other crops. Compared with the average-technical-efficiency model, corn acres were increased by 6 million in the advanced-technical-efficiency model, replacing 5 million acres of soybeans and about 1 million acres of oats and meadow combined.

In the average-technical-efficiency model, 1 million cows are raised, and they have a calf crop of 677,000 head; 592,000 being fattened to slaughter weights and 85,000 being exported from Iowa as feeders. No feeder calves are imported into Iowa. On the other hand, 646,000 cows are raised in the advanced-techni-

Table 14. (Cont'd).

Item	Unit	Solution number 11	12	13	14	15
Prices						
Hogs	dollars/cwt.	12.50	12.50	12.50	12.50	12.50
Cattle	dollars/cwt.	20.00	21.00	22.00	23.00	24.00
Crops						
Corn	1,000 acres	12,224	12,197	12,303	12,737	12,661
Soybeans	1,000 acres	5,556	5,583	5,478	4,914	4,696
Oats	1,000 acres	2,493	2,493	2,493	2,493	2,387
Rotation meadow	1,000 acres	3,131	3,131	3,131	3,294	3,660
Beef						
Cows	1,000 head	1,069	1,110	458	182	213
Calves sold	1,000 head	16	0	0	0	0
Calves purchased	1,000 head	0	0	3,315	5,783	8,357
Total live beef sold	million lbs.	900	952	3,806	6,113	8,790
Hogs						
Total live hogs sold	million lbs.	5,576	5,543	5,092	4,356	2,782
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	816	720	528	264	264
Beef housing	1,000 a.u.	0	0	0	310	1,244
Beef feeding	1,000 head	0	0	0	111	399
Resources						
Borrowed funds	million dol.	0	0	0	10	12
Cash invested off farm	million dol.	1,625	1,617	1,316	1,020	591
Labor hired	million m.h.	7	7	7	9	10
Operator and family labor not used	million m.h.	111	110	106	101	95
Revenue	million dol.	1,064	1,073	1,090	1,121	1,167

Item	Unit	Solution number 16	17	18	19	20
Prices						
Hogs	dollars/cwt.	12.50	13.00	13.00	13.00	13.00
Cattle	dollars/cwt.	26.00	20.00	21.00	22.00	23.00
Crops						
Corn	1,000 acres	13,838	12,255	12,257	12,421	12,869
Soybeans	1,000 acres	2,419	5,525	5,523	5,359	4,824
Oats	1,000 acres	2,755	2,493	2,493	2,493	2,449
Rotation meadow	1,000 acres	4,392	3,131	3,131	3,131	3,262
Beef						
Cows	1,000 head	196	1,012	953	503	322
Calves sold	1,000 head	0	85	16	0	0
Calves purchased	1,000 head	12,405	0	255	2,319	4,734
Total live beef sold	million lbs.	12,945	779	1,063	2,820	5,152
Hogs						
Total live hogs sold	million lbs.	509	7,765	7,487	7,191	5,950
Livestock facilities added						
Hog farrowing	1,000 sows	0	0	0	0	0
Hog feeding	1,000 pigs	0	8,592	7,112	6,040	2,880
Beef housing	1,000 a.u.	3,716	0	0	0	217
Beef feeding	1,000 head	2,632	0	0	0	1
Resources						
Borrowed funds	million dol.	301	0	0	0	5
Cash invested off farm	million dol.	53	1,469	1,472	1,306	1,053
Labor hired	million m.h.	11	9	9	9	9
Operator and family labor not used	million m.h.	83	83	86	86	85
Revenue	million dol.	1,296	1,112	1,118	1,132	1,154

cal-efficiency model at the same hog and cattle price combination, with all the 502,000-head calf crop being fattened in Iowa. In addition, nearly 2 million head of feeder cattle are imported. Additional cattle housing and feeding facilities must be built to feed the large number of cattle raised.

Solution 17 in table 14 and solutions 28, 32, and 36 in table 3 show that it was profitable for Iowa farmers to use substantially more capital and labor in agricultural production in the advanced-technical-efficiency model. As a result of the more efficient use of resources, farmers could make considerably more income -- assuming that factor and product prices would not change as a result of the increased production.

COMPARISON OF HOG AND CATTLE SUPPLY CURVES UNDER THE TWO LEVELS OF TECHNICAL EFFICIENCY

The effects of the change in level of efficiency on optimal hog and cattle production in Iowa can be compared in figs. 2 and 3. The "average technical efficiency" curves in the two figures show that total production of hogs and cattle in Iowa could be increased at historical price levels if farmers were to (a) perfectly allocate their resources among the various enterprises and (b) continue to use an *average* level of technical efficiency. For example, the average-technical-efficiency model shows that Iowa farmers could sell, at $14-hogs and $24-cattle, the same quantity of cattle and 1.86 times the quantity of hogs as was sold in Iowa in 1965. At 1965 prices, even more livestock could be produced and sold. But if Iowa farmers were to (a) perfectly allocate their resources among the various enterprises and (b) use an advanced level of technical efficiency (i.e., use the most efficient farming methods known), production of hogs and cattle could be increased even more. A comparison between the curves labeled "average technical efficiency" and "advanced technical efficiency" in both figs. 2 and 3 indicates the magnitude of the increase in production potential caused by the change in technology. These figures indicate that Iowa's agricultural production potential may be increased more by the change in the level of technical efficiency than by the perfect allocation of resources in agriculture.

These results show how technology can affect the production potential of a given area. If Iowa farmers were limited to the use of production techniques commonly used during 1957-1961, the production potential of Iowa agriculture would not greatly exceed actual production. But if every farmer in Iowa were to use the best production techniques already known in 1961, the production potential would greatly exceed actual production levels.

Thus, for Iowa agriculture to continually become more efficient, two forces must be working. By the continual discovery of new and more efficient production techniques, the production potential from the resources on Iowa farms continues to increase, and the advanced-technical-efficiency curves in figs. 2 and 3 shift to the right. But changes in potential, *per se*, do not affect efficiency. The advanced farming techniques must be passed on to the farmers. Then the average-technical-efficiency curves in figs. 2 and 3 will shift closer to the advanced-technical-efficiency curves. Increased efficiency enables more to be produced from the resources on Iowa farms or, conversely, enables fewer resources to produce a given quantity of agricultural commodities.

Table 14. (Cont'd).

Item	Unit	Solution number 21	22	23	24	25	26
Prices							
Hogs	dollars/cwt.	13.00	13.00	14.00	14.00	14.00	14.00
Cattle	dollars/cwt.	24.00	26.00	22.00	23.00	24.00	26.00
Crops							
Corn	1,000 acres	12,917	14,177	13,202	13,442	13,668	15,431
Soybeans	1,000 acres	4,577	2,181	4,524	4,283	3,824	1,056
Oats	1,000 acres	2,392	2,897	2,466	2,466	2,488	2,876
Rotation meadow	1,000 acres	3,518	4,150	3,213	3,213	3,425	4,042
Beef							
Cows	1,000 head	276	196	424	404	365	256
Calves sold	1,000 head	0	0	36	0	0	0
Calves purchased	1,000 head	6,860	11,552	1,569	2,337	4,188	9,356
Total live beef sold	million lbs.	7,302	12,066	1,942	2,753	4,628	9,856
Hogs							
Total live hogs sold	million lbs.	4,574	1,818	10,067	9,581	8,315	5,094
Livestock facilities added							
Hog farrowing	1,000 sows	0	0	476	401	152	0
Hog feeding	1,000 pigs	1,024	264	18,112	16,176	11,056	1,656
Beef housing	1,000 a.u.	634	3,162	0	0	187	1,852
Beef feeding	1,000 head	159	1,870	0	0	0	376
Resources							
Borrowed funds	million dol.	12	215	0	0	0	68
Cash invested off farm	million dol.	772	95	1,054	997	874	248
Labor hired	million m.h.	10	12	11	11	12	16
Operator and family labor not used	million m.h.	83	74	55	55	58	55
Revenue	million dol.	1,191	1,307	1,234	1,248	1,266	1,350

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APPENDIX

Table A-1. Resource supplies on representative farms and on the sum of all farms in Iowa.

	Unit	Area 1: 1	2	3
Land				
Class 3 cropland	acres	0	0	0
Class 2 cropland	acres	16	32	60
Class 1 cropland	acres	59	120	222
Permanent pasture	acres	7	14	29
Livestock facilities				
Central hog farrowing	sows	12	17	23
Portable hog farrowing	sows	0	12	22
Confinement hog feeding	pigs	0	80	191
Portable hog feeding	pigs	107	127	161
Beef housing	a.u.[a]	21	33	54
Beef feeding, low mech.	head	51	0	0
Beef feeding, high mech.	head	0	100	217
Capital				
Cash	dollars	11,420	14,016	24,073
Chattel mortgage credit	dollars	2,438	4,153	5,869
Operator and family labor				
Annual	m.h.[b]	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	49	211	761

[a]Animal unit.
[b]Man-hour.

Table A-1. (Cont'd).

	Unit	Area 2: 4	5	6	7
Land					
Class 3 cropland	acres	16	37	77	132
Class 2 cropland	acres	13	30	62	107
Class 1 cropland	acres	29	67	137	235
Permanent pasture	acres	11	13	46	8
Livestock facilities					
Central hog farrowing	sows	10	12	17	0
Portable hog farrowing	sows	0	4	11	12
Confinement hog feeding	pigs	0	57	76	0
Portable hog feeding	pigs	60	110	161	90
Beef housing	a.u.	22	31	51	36
Beef feeding, low mech.	head	38	0	0	60
Beef feeding, high mech.	head	0	71	127	0
Capital					
Cash	dollars	6,717	12,725	28,780	24,318
Chattle mortgage credit	dollars	1,167	3,768	5,502	7,373
Operator and family labor					
Annual	m.h.	2,000	2,330	2,520	2,250
February	m.h.	177	195	222	211
March	m.h.	202	220	252	241
April	m.h.	202	220	252	241
May	m.h.	227	270	307	296
June	m.h.	227	320	357	346
July	m.h.	227	320	357	346
September	m.h.	227	245	282	271
October	m.h.	227	245	282	271
November	m.h.	202	220	252	241
Hired labor limit	m.h.	25	114	1,048	1,977

Table A-1. (Cont'd).

	Unit	Area 3: 8	9	10
Land				
Class 3 cropland	acres	7	14	29
Class 2 cropland	acres	35	70	142
Class 1 cropland	acres	22	65	133
Permanent pasture	acres	9	12	32
Livestock facilities				
Central hog farrowing	sows	0	12	12
Portable hog farrowing	sows	14	0	9
Confinement hog feeding	pigs	0	0	0
Portable hog feeding	pigs	93	157	226
Beef housing	a.u.	23	29	40
Beef feeding, low mech.	head	48	100	0
Beef feeding, high mech.	head	0	0	147
Capital				
Cash	dollars	11,050	14,370	30,172
Chattel mortgage credit	dollars	3,533	3,098	5,597
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	43	128	1,553

Table A-1. (Cont'd).

	Unit	Area 4: 11	12	13
Land				
Class 3 cropland	acres	0	0	0
Class 2 cropland	acres	8	17	31
Class 1 cropland	acres	68	140	255
Permanent pasture	acres	8	7	25
Livestock facilities				
Central hog farrowing	sows	9	11	15
Portable hog farrowing	sows	5	7	9
Confinement hog feeding	pigs	58	59	89
Portable hog feeding	pigs	82	130	162
Beef housing	a.u.	19	25	36
Beef feeding, low mech.	head	43	62	0
Beef feeding, high mech.	head	0	0	98
Capital				
Cash	dollars	10,687	15,265	20,653
Chattel mortgage credit	dollars	2,888	4,546	5,165
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	178	217	949

Table A-1. (Cont'd).

	Unit	Area 5 14	15	16
Land				
Class 3 cropland	acres	14	29	29
Class 2 cropland	acres	18	40	78
Class 1 cropland	acres	26	55	109
Permanent pasture	acres	17	35	117
Livestock facilities				
Central hog farrowing	sows	0	0	26
Portable hog farrowing	sows	13	19	0
Confinement hog feeding	pigs	0	0	147
Portable hog feeding	pigs	96	231	132
Beef housing	a.u.	16	26	65
Beef feeding, low mech.	head	21	52	0
Beef feeding, high mech.	head	0	0	175
Capital				
Cash	dollars	10,726	14,631	19,764
Chattel mortgage credit	dollars	3,000	3,036	2,506
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	29	131	924

Table A-1. (Cont'd).

	Unit	Area 6 17	18	19
Land				
Class 3 cropland	acres	27	56	96
Class 2 cropland	acres	17	35	61
Class 1 cropland	acres	15	32	56
Permanent pasture	acres	27	49	114
Livestock facilities				
Central hog farrowing	sows	0	0	22
Portable hog farrowing	sows	10	19	0
Confinement hog feeding	pigs	0	0	27
Portable hog feeding	pigs	75	115	0
Beef housing	a.u.	15	26	168
Beef feeding, low mech.	head	23	33	56
Beef feeding, high mech.	head	0	0	0
Capital				
Cash	dollars	5,590	14,797	13,727
Chattel mortgage credit	dollars	1,818	2,943	1,290
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	44	172	343

Table A-1. (Cont'd).

	Unit	Area 7 20	21	22
Land				
Class 3 cropland	acres	0	0	0
Class 2 cropland	acres	13	28	54
Class 1 cropland	acres	57	121	232
Permanent pasture	acres	11	16	33
Livestock facilities				
Central hog farrowing	sows	11	22	21
Portable hog farrowing	sows	0	0	9
Confinement hog feeding	pigs	0	0	148
Portable hog feeding	pigs	64	190	145
Beef housing	a.u.	15	24	45
Beef feeding, low mech.	head	23	48	0
Beef feeding, high mech.	head	0	0	104
Capital				
Cash	dollars	11,370	15,751	27,224
Chattel mortgage credit	dollars	1,880	4,650	7,216
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	61	219	1,175

Table A-1. (Cont'd).

	Unit	Area 8 23	24	25
Land				
Class 3 cropland	acres	0	0	0
Class 2 cropland	acres	18	36	60
Class 1 cropland	acres	59	117	194
Permanent pasture	acres	10	39	44
Livestock facilities				
Central hog farrowing	sows	11	25	22
Portable hog farrowing	sows	9	0	16
Confinement hog feeding	pigs	0	0	182
Portable hog feeding	pigs	150	201	167
Beef housing	a.u.	24	31	54
Beef feeding, low mech.	head	49	62	0
Beef feeding, high mech.	head	0	0	127
Capital				
Cash	dollars	10,890	22,571	26,447
Chattel mortgage credit	dollars	2,735	4,759	6,313
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	98	336	1,301

Table A-1. (Cont'd).

	Unit	Area 9		
		26	27	28
Land				
Class 3 cropland	acres	5	21	40
Class 2 cropland	acres	13	51	98
Class 1 cropland	acres	16	65	126
Permanent pasture	acres	14	27	58
Livestock facilities				
Central hog farrowing	sows	0	18	21
Portable hog farrowing	sows	7	0	9
Confinement hog feeding	pigs	0	0	0
Portable hog feeding	pigs	50	166	313
Beef housing	a.u.	10	26	41
Beef feeding, low mech.	head	18	51	0
Beef feeding, high mech.	head	0	0	104
Capital				
Cash	dollars	4,040	14,482	25,746
Chattel mortgage credit	dollars	2,813	3,464	5,729
Operator and family labor				
Annual	m.h.	2,000	2,330	2,520
February	m.h.	177	195	222
March	m.h.	202	220	252
April	m.h.	202	220	252
May	m.h.	227	270	307
June	m.h.	227	320	357
July	m.h.	227	320	357
September	m.h.	227	245	282
October	m.h.	227	245	282
November	m.h.	202	220	252
Hired labor limit	m.h.	29	124	1,357

Table A-1. (Cont'd).

	Unit	Area 10			Total[c]
		29	30	31	
Land					
Class 3 cropland	acres	16	33	60	2,188,315
Class 2 cropland	acres	32	64	117	5,946,756
Class 1 cropland	acres	13	25	46	15,468,009
Permanent pasture	acres	21	38	98	4,117,047
Livestock facilities					
Central hog farrowing	sows	13	23	24	2,020,260
Portable hog farrowing	sows	0	0	12	952,181
Confinement hog feeding	pigs	48	84	232	6,917,087
Portable hog feeding	pigs	72	49	126	19,073,118
Beef housing	a.u.	20	33	64	5,120,989
Beef feeding, low mech.	head	33	65	0	4,598,764
Beef feeding, high mech.	head	0	0	156	6,113,800
Capital					
Cash	dollars	6,856	16,871	27,440	2,361,985,100
Chattel mortgage credit	dollars	3,671	2,772	4,812	568,497,650
Operator and family labor					
Annual	m.h.	2,000	2,330	2,520	326,001,430
February	m.h.	177	195	222	28,160,373
March	m.h.	202	220	252	31,926,668
April	m.h.	202	220	252	31,926,668
May	m.h.	227	270	307	38,334,788
June	m.h.	227	320	357	43,618,438
July	m.h.	227	320	357	43,618,438
September	m.h.	227	245	282	35,692,963
October	m.h.	227	245	282	35,692,963
November	m.h.	202	220	252	31,926,668
Hired labor limit	m.h.	76	166	1,209	64,420,868

[c]The state total is a weighted sum of the representative farms. The weights are given in table 2.

Table A-2. Purchase cost and credit made available by the purchase of a calf and a yearling.

Choice beef sale price	Purchase of calf		Purchase of yearling	
	Cost[a]	Credit available[b]	Cost[c]	Credit available[b]
$16	$ 75.37	$64.064	$114.40	$ 97.24
17	79.77	67.804	121.55	103.32
18	84.17	71.544	128.70	109.40
20	92.97	79.024	143.00	121.55
24	110.57	93.984	171.60	145.68

[a]Computed by multiplying the weight (440 pounds) by the purchase price (the choice price, *plus* a margin of $1.13).
[b]Credit can be obtained on up to 85 percent of the purchase cost.
[c]Computed by multiplying the weight (715 pounds) by the purchase price (the choice price with no margin).

Table A-3. Yield of oats and hay per acre of rotation by geographic area of Iowa.

Crop and rotation	Unit	Area 1	2	3	4	5	6	7	8	9	10
Oats:											
CCOM$_1$	bushels	13.75	13.75	12.50	15.25	14.00	14.25	15.25	16.75	15.75	15.50
CSOM$_1$	bushels	13.75	13.75	12.50	15.25	14.00	14.25	15.25	16.75	15.75	15.50
CSSOM	bushels	11.00	11.00	10.00	12.20	11.20	11.40	12.20	13.40	12.60	12.40
CCOM$_2$	bushels	14.50	11.00	10.25	13.50	11.50	12.50	11.75	16.00	15.00	14.50
CSOM$_2$	bushels	14.50	11.00	10.25	13.50	11.50	12.50	11.75	16.00	15.00	14.50
CSSOMM	bushels	9.67	7.33	6.83	9.00	7.67	8.33	7.83	10.67	10.00	9.67
COMM[a]	bushels		8.25	9.75		7.50	9.75			10.50	11.00
Hay:											
CCOM$_1$	tons	0.85	0.82	0.72	0.80	0.80	0.72	0.85	0.88	0.82	0.82
CSOM$_1$	tons	0.85	0.82	0.72	0.80	0.80	0.72	0.85	0.88	0.82	0.82
CSSOM	tons	0.68	0.66	0.58	0.64	0.64	0.58	0.68	0.70	0.66	0.66
CCOM$_2$	tons	0.80	0.68	0.70	0.75	0.72	0.68	0.62	0.85	0.78	0.78
CSOM$_2$	tons	0.80	0.68	0.70	0.75	0.72	0.68	0.62	0.85	0.78	0.78
CSSOMM	tons	1.07	0.90	0.94	1.00	0.97	0.90	0.84	1.14	1.04	1.04
M$_2$	tons	3.20	2.70	2.80	3.00	2.90	2.70	2.50	3.40	3.10	3.10
M$_3$[a]	tons		2.70	2.10		1.60	1.90			2.20	2.70
COMM[a]	tons		1.35	1.05		0.80	0.85			1.10	1.35

[a]This rotation was not an alternative in areas 1, 4, 7 and 8.

Table A-4. Yield of corn and soybeans per acre of rotation by geographic area of Iowa.

Crop and rotation	Unit	Area 1	2	3	4	5	6	7	8	9	10
Corn:											
Continuous	bushels	81.00	80.00	74.00	87.00	87.00	80.00	89.00	100.00	92.00	94.00
CS	bushels	40.50	40.00	37.00	43.50	43.50	40.00	44.50	50.00	46.00	47.00
CCOM$_1$	bushels	42.00	41.50	38.50	45.00	45.00	41.50	46.00	51.50	47.50	48.50
CSOM$_1$	bushels	21.25	21.00	19.50	22.75	22.75	21.00	23.25	26.00	24.00	24.50
CSSOM	bushels	16.80	16.60	15.40	18.00	18.00	16.60	18.60	20.80	19.20	19.40
CCOM$_2$	bushels	35.75	33.75	35.75	39.25	38.75	34.75	33.75	48.25	40.25	44.75
CSOM$_2$	bushels	17.75	16.75	18.25	20.00	19.50	17.50	17.00	24.25	20.25	22.50
CSSOMM	bushels	11.83	11.17	12.17	13.33	13.00	11.67	11.33	16.17	13.50	15.00
COMM[a]	bushels		13.75	13.50		10.50	12.75			13.50	17.25
Soybeans:											
CS	bushels	16.00	16.00	15.50	17.00	17.50	16.50	16.50	18.50	17.50	17.50
CSOM$_1$	bushels	8.25	8.25	8.00	8.75	9.00	8.50	8.50	9.50	8.00	8.00
CSSOM	bushels	12.40	12.40	12.00	13.20	13.60	12.80	12.80	14.40	13.60	13.60
CSOM$_2$	bushels	7.50	7.50	7.25	8.00	8.25	7.75	7.75	8.75	8.25	8.25
CSSOMM	bushels	9.67	9.67	9.33	10.33	11.33	10.00	10.00	11.33	10.67	10.67

[a]This rotation was not an alternative in areas 1, 4, 7 and 8.