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A system for partial optimization in farm planning

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A SYSTEM FOR PARTIAL OPTIMIZATION IN FARM PLANNING

by

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HISTORY OF LINEAR PROGRAMMING AS IT APPLIES TO FARM PLANNING

Since linear programming was developed shortly after World War II economists have found many uses for it. Agricultural economists have found it particularly useful in determining optimum organizations of farms, in specifying farm adjustments, in determining profit maximizing mixes of commodities, and in indicating optimum patterns of interregional resource use and product specialization (4,8).

Agricultural economists dealing with problems in farm management have found the technique of linear programming especially useful in farm planning. The first attempts in 1953-54 to use linear programming as a farm planning tool were somewhat crude and gave rather general answers. However, much of the difficulty with the early work resulted from the necessity to seek solutions with the aid of desk calculators (7,15). With the advent of better, more refined methods and high speed electronic computers with large capacities, linear programming has become extremely useful as a farm planning tool.

In the recent past much of the effort in using linear programming for farm planning has been directed into one of two areas. Either the work has been solely research oriented, using linear programming as a tool to solve a specific problem defined by the researcher or specific farms in separate soil associations have been programmed with a wide variety of alternatives. In turn, the results from these farms have been published as general guidelines for farms in that same association (9,10,18,22).

Linear programming has been an excellent tool for research and for setting general guidelines, but it has been used little in solving problems or in forward planning at the individual farm level. The advantages of using the tool in farm planning are many, and more and more farmers are becoming interested in its use (1,6).

There seem to be two basic reasons why linear programming has not been used extensively for individual farm planning. First, input-output data is difficult to estimate accurately for the individual farm. Most farmers, even those who keep excellent records, do not have sufficient data to construct a usable programming model (16). In addition, historic data may be of little use in estimating production coefficients when shifts in production methods or volume are anticipated.

Second, even if all the necessary data were available, it would take considerable technical manpower to construct a linear programming matrix of sufficient size to include all the desired alternatives.

With present and potential data storage capacities of computers, it seems logical that some "master model" containing a wide variety of alternatives reflecting various production, cost, and management levels could be constructed and stored in the computer. A farm operator or planner could then choose those activities which best describe his unique situation. By specifying important resource or facility constraints, he could obtain an optimum plan, using a given set of price expectations, also stored, or a set specified by him.

Past arguments against using previously determined input-output data, or budgeting data, have been directed at the idea of non-applicability. In other words, if the data is not derived from the individual farm, it will not be accurate enough to give a usable solution. McFarquhar counters the argument by stating that derived data also involves a considerable amount of questionable estimating. He believes that if enough alternatives are considered using localized budgeting materials, one method may be as accurate as the other (19).

During the last two years, the Extension Farm Management staff at Iowa State University has programmed several farm situations. These examples have been used primarily for teaching management principles. However, during the presentation of the programming material, farmers often raised questions about the possible results of the examples under wider ranges of production methods, price expectations or resource constraints. It became evident that farm operators prefer to compare several alternative plans and/or relate them to one optimum plan.

Since linear programming typically provides only one optimum solution, the planner does not know how close other plans might compare in income or resource use. The Extension Farm Management staff at Iowa State University has also found that many farmers find it difficult to think in terms of shifting completely into or out of a given enterprise as prices or resources change. Rather they prefer to hold certain enterprises constant while allowing others to change, given the fixed level of resources.

If a method could be devised to allow for partial optimization, it could be useful for the individual farm operator who might wish to compare various farm plans to his present operation and to some optimum plan. Such a method could also prove helpful in the classroom situation in teaching farm management principles.

Such a model could also allow for decreasing cost or increasing income activities. Past methods of farm planning using linear programming alone have not been able to properly evaluate decreasing cost enterprises. Coupling such enterprises with a budgeting or partial optimization routine would increase the effectiveness of such a model.

Thesis Objective

The objective of this thesis is to attempt to construct a sample linear programming model which would meet the goals just mentioned, thus making linear programming both available and useful to larger numbers of farm operators. First of all, the model needs to be constructed in such a manner that the basic input-output data can be stored easily or left undisturbed as various farm situations are programmed.

Second, the model must be constructed in such a way that price expectations and resource availabilities can be easily altered from one solution to the next. Activity prices, therefore, must be formulated in terms of commonly used marketing units, such as livestock prices in hundredweight units instead of animal units. Crop selling or buying activities must be in terms of tons or bushels instead of acres.

Third, the printed output for each problem should include a written description of the optimum solution. Such an output report would allow farm operators or farm management specialists who are unfamiliar with the model to understand and interpret the output report. Professional staff time in the field could thereby be reduced. The output report should, therefore, give a written, instead of a numerically coded, identification of the activities included in or excluded from the optimum plan. An accurate description of resource use and income generated should also be provided.

Fourth, the model should be built to allow for complete budgeting, partial optimization, or complete optimization of a given situation. Such a model would permit a farm operator to try out several farm plans to compare incomes or resource use or to keep certain facets of his business organization fixed while optimizing on the remainder of his resources.

Such a model would seem to have a wide range of possible uses. It would eliminate much of the preparatory work usually encountered in gathering data and constructing a model. The possibility of optimizing, partially optimizing, or budgeting would give much greater flexibility with the same model. Because budgeting problems would be computed with a linear programming method, the user could also learn the computed marginal value of scarce resources and the income penalties associated with activities not in the solution. This information has not been available from conventional budgeting methods.

REVIEW OF FARM PLANNING APPLICATION OF LINEAR PROGRAMMING

As mentioned earlier, linear programming first was applied to farm planning problems during 1953-54. The early attempts in farm planning were somewhat crude and did not give real insight into the nature of the farm businesses being considered, primarily because the computational methods at that time still forced the planner to compute the problems with a desk calculator, limiting the number of possible alternatives and production coefficients.

King presented an example of an early attempt to use activity analysis, a computational method of linear programming, in 1953 (15). One of his examples involved a family farm with 60 acres of cropland in the Northern Tidewater of North Carolina. He considered only six enterprises: Irish potatoes, corn, soybeans, cropland pasture used for beef production, fall lettuce and fall cabbage. The fixed resources specified were cropland, production capital, and operator labor defined in two-month intervals. His method of budgeting the input-output coefficients entailed defining factor requirements in terms of $100 net revenue units. Capital requirements were given in terms of yearly cash expenditure requirements to produce $100 of net revenue.

With resources limited to 60 acres of cropland and $2000 of production capital, the optimum solution was determined to be 61.086 units of Irish potatoes, 16.773 units of beef, and 0.213 units of fall lettuce. Net revenue produced was $7807.20.

While such a model is satisfactory mathematically, its accuracy and applicability for farm planning purposes may be questioned. The first item that comes into question is the unit of production, $100 of net revenue, associated with the activities. While such a unit may give the same answer as any other unit, determining and understanding the input coefficients is confusing. Cost-of-production data is seldom listed in any other way than animal or acre units. Because the production units are specified in terms of $100 net revenue, the net prices of the activities are equal. If the planner wished to change the price expectations or interpret the income penalties computed for activities not in the solution, much additional calculating would be necessary to relate the price changes or income penalties to animal or acre units.

Offering only six activities illustrates the potential of activity analysis for farm planning, but someone who wished to seriously look at the alternatives open to an individual farm operator would want to consider many more alternatives. If the six activities are the only ones the farmer wished to consider, a farm planning model should include alternatives within potato, corn, soybean, lettuce or cabbage production. There may be as much difference among activities formulated within enterprises as between them.

Much the same comment could be made about the resource restrictions. King included land, labor and capital, the three basic limitations in most businesses. If the 60 acres of land are homogeneous, one could scarcely argue with a single land restriction. The weakness of the resource restrictions lies in the difference between the labor and capital restrictions. Labor is precisely defined in terms of operator hours available in two-month intervals. Capital, on the other hand, is defined as a single yearly restriction on production capital, which is not defined clearly. King states that it includes basic production expenses, but he does not state if it includes other costs. Acknowledging that labor is a flow resource while capital is a stock resource, a single yearly capital requirement lacks precision. The various activities considered may require capital at different times of the year and may cease requiring capital long before the year is completed. They may also generate income which in turn can be used for succeeding activities. Thus, a $2000 capital limitation may mean the peak net capital usage will be much less than the total limitation.

In summary, King's model serves the purpose of illustrating the procedure of activity analysis. However, his model falls short of meeting the needs of adequate farm planning methods. More activities need to be considered, capital usage should be more clearly defined, and the production units should be defined in more conventional terms.

A much more thorough application of linear programming reported about the same time is illustrated by Bowlen (3). Bowlen's objective was to determine the crop combinations that would maximize income under various resource situations for the major soil associations in Iowa. He had 14 representative townships throughout the state selected on the basis of the major soil association in each township. Land resources for each farm were limited to 160 acres, which was the most common size of farm at that time. For each township farm it was assumed that 154 acres would be tillable. The minimum acreage of hay and oats was determined for each farm, leaving the remainder open to other crop alternatives.

Labor resources for the operator were defined as 260 hours per month. Labor requirements for cropping activities were determined on a monthly basis. The amount of labor available for cropping activities was determined by first computing labor availability for field work considering the weather factor. After total available cropping labor was determined, that amount of labor necessary for the minimum hay and oat acreage on each farm was subtracted, leaving the residual labor available for other cropping activities.

Two other labor resource situations were also considered. The first was for an additional 130 hours of family labor per month. The second was for unlimited hired labor available at an hourly wage.

Capital resources were divided into three levels. The first level was the average capital expenditure level for all Iowa farms in 1952. The second level was for 150 percent of the first level. The third level allowed for an unlimited supply of capital, which meant the farmer had access to all the capital he considered would be profitable in his operation.

As with land and labor, capital requirements for the minimum hay and oat acreage were first subtracted, with the remainder available for other cropping activities. Capital coefficients for each cropping activity were given as a single yearly figure on a per acre basis. The capital coefficient for each crop included both fixed and variable costs.

The defined fixed costs included overhead tractor costs, tractor operating costs, machinery depreciation, seed costs, and building costs. The variable costs were defined as real estate taxes, machine and labor hire. It should be noted that a fixed labor requirement was included in the capital costs of some of the cropping activities.

The cropping activities considered were corn, soybeans, oats, and flax and wheat in some areas. Each activity was defined in terms of acre units.

The net price for each acre activity was total revenue minus total costs. Because it was not the objective to consider livestock enterprises, they were omitted.

The results from such a model list the acres planted of each cropping enterprise, the monthly labor use, and capital use. In comparison to King's model mentioned earlier, Bowlen's use of activity analysis for farm planning was superior. The manner in which Bowlen derived his labor coefficients was thorough and entirely applicable to farm planning models being used at the present time. The acre units of production are much easier to interpret in terms of input-output data. The land resources were realistically separated into minimum required legume production, with only the remaining acreage available for optimization.

Analysis of Bowlen's model in terms of its applicability to general farm planning situations reveals some of the same shortcomings as King's model.

The first shortcoming is the lack of marketing units or activities to facilitate consideration of alternative price expectations. With Bowlen's method, a cropping activity included the growing costs and the sale price per acre. With 14 different farm situations and possibly as many cost and yield differences, each farm situation required recalculating the net price for each crop activity. A method of transfer rows and crop marketing activities would have facilitated much of the detail work required for price or yield changes.

The second shortcoming in Bowlen's model involves two aspects of his method of handling production capital. He indicated that each capital coefficient involved such costs as overhead tractor costs, tractor operating costs, machinery depreciation, seed costs, building costs, real estate taxes, and machine and labor hire. Since Bowlen assumed a specific land resource and a given set of machinery, many of the capital costs he listed would be fixed costs to the entire business and not allocable to a given unit of production. The fixed costs should have been independently subtracted from the total income generated, since linear programming maximizes returns to the fixed factors to reach an optimum plan (8).

Bowlen also used King's method of listing his capital coefficients. The capital requirements are given as a single yearly requirement for each crop, regardless of the length and season of time each crop activity requires capital. The actual variable capital required in any one time period may be much less than would be indicated by Bowlen's model, especially with unlimited capital. Some work has, however, been done with redefining capital requirements and time periods.

Stewart stated that more attention needs to be placed on the derivation of capital coefficients since capital is so often the crucial limiting resource (23). In considering the single yearly capital coefficient, Stewart states:

> "It is difficult to attach realistic meaning to the relationship given in this form (single yearly requirement). Clearly the operating capital requirements for any farm programme may not be expressed in terms of discrete coefficients for each activity unless there is some account taken of the time pattern of income from and expenditure on each activity. If no such account is taken, then the relationship in the above form (single linear relationship) violates the assumption of independence which is implicity in the linear model. That is, unless the total farm product is sold on the 365th day of the year being considered, then the total effective capital requirements of the whole farm programme will be less than the sum of the capital requirements of each enterprise." (23, p. 464)

Stewart then proceeded to set up a theoretical "capital profile" similar to the manner in which labor requirements are allocated seasonally or monthly. The major difference is that, unlike unused labor, unused capital in one period can be carried forward and used in the next period. Therefore, the capital profile was actually a series of cumulative balances. During the year, a production activity either requires more capital, enlarging the profile, or gives up capital in the form of receipts, decreasing the profile.

Nonassignable, or fixed, costs were deducted from the original capital available, leaving the residual to meet the variable cost requirements. With such a method, all capital costs, including fixed costs, must be met with the capital resource, but fixed costs are not broken down among the activities, as they are in Bowlen's work.

Stewart then constructed a linear programming problem using a New Zealand farm with 305 acres for mixed cropping and lamb feeding. The activities considered were five cash crops, five intermediate crops, and three sheep enterprises. Capital requirements were listed on a monthly basis, starting June 1. The solution showed capital was limiting in two of the twelve months. Each of the remaining months had a positive capital balance.

By allocating the capital requirements on a monthly or seasonal basis, a farm planner might determine the months or seasons in which capital would be limiting. If the limiting period was short in duration, the operator might be able to gain an extension of credit use and expand his operation to more fully utilize available capital the rest of the year. In such a case, the capital limitation in the restricting period might be relaxed because of the positive balances maintained during the rest of the year.

In summary, Stewart illustrated that single seasonal capital coefficients may not be of sufficient accuracy to describe meaningfully the relationship between capital requirements and availability. Because capital is a stock resource it doesn't follow that monthly or seasonal capital coefficients are not as important as monthly or seasonal labor coefficients. Capital, like labor, may be limiting in only one period. The capital resource would have a positive marginal value only in the limiting period and not for the whole year as it would with the single sum coefficient.

Mention has been made that farmers are becoming increasingly familiar with linear programming and its potential applications to farm planning problems. An example of how farmers are learning of linear programming and how it is being used to assist in specific farm situations is illustrated in a popular journal by Huheey (12). The article cites the work done by R. J. Becker of Arizona State University and Becker's earlier work at the University of Pennsylvania.

After describing what linear programming is and what it can and cannot do, Huheey reports the planning process using an actual farm situation. The necessary input-output data was collected by an on-the-farm visit lasting little more than an hour. Two staff members then developed the enterprise budgets in a matrix form. The types of activities and resource restrictions used are listed in Table 1.

From the table one can observe immediately that no capital restrictions or requirements are included. The assumption was made that capital would not be a limiting factor within the resource restrictions specified.

Table 1. Activities and resource restrictions used in model application of linear programming*

Activities	Unit	Resources	
Dairy Cow	1 Producing Cow	Max. Acres Owned	660
Cotton	1 Acre raised and sold	Max. Acres Rentable	340
Sell Hay	1 Acre raised and sold	Max. Hours Operator Labor 1	800
Sell Barley	1 Acre raised and sold	Max. Hours Operator Labor 2	800
Alfalfa Hay	1 Acre raised and fed	Max. Hours Operator Labor 3	800
Barley	1 Acre raised and fed	Max. Hours Operator Labor 4	800
Sorghum Silage	1 Acre raised and fed	Max. Hours Operator Labor 5	1600
Buy Alfalfa Hay	cwt. bought	Max. Dairy Cows	360
Buy Cottonseed Meal	cwt. bought	Pounds TDN Transfer	0
Buy Bedding	ton bought	Pounds DP Transfer	0
Rent Land	1 Acre rented	Pounds DM Transfer	0
Hire Labor 1	1 Hour - March-April	Max. Acres Cotton	147
Hire Labor 2	1 Hour - May-June	Tons Bedding Transfer	1
Hire Labor 3	1 Hour - July-August		
Hire Labor 4	1 Hour - September-October		
Hire Labor 5	1 Hour - November-February		

*(12, p. 65).

This obviated the necessity of specifying capital requirements on the activities.

Realizing that the model was built for a specific farm problem, one can identify several shortcomings that would lead to unnecessary difficulties in interpretation and/or to additional computational work. First, the cropping activity units are divided between acre units and hundredweight units, depending upon whether the crop is sold or bought. Such a division requires that the program planner always reinterpret the results to the farm operator. Also, if additional solutions are sought with crop price changes, the producing and selling activities would require additional computational work to arrive at a new net price.

The same argument can be applied to the dairy cow activity if milk prices were to be varied. The inclusion of several milk and grain transfer rows and selling activities with the activities defined in conventional marketing units would simplify the interpretation of results and facilitate multiple price programming.

Huheey emphasized the small amount of time required to derive the necessary input-output data, build the model, and make the machine computation. The farm visit took 75 minutes, constructing the matrix took eight technical man-hours and the machine computation took 30 seconds. Considering the small number of alternatives considered and amount of technical labor to build the rather small model, one wonders at the possibility of increasing the efficiency further. Certainly if additional alternatives or price situations were to be considered, additional staff time would be necessary to rebuild a matrix. Staff time would also be necessary to interpret the results to the farm operator.

One additional factor was noted briefly, but no importance was given to it. With the Becker approach each problem solution requires that a new set of data cards be written and punched. In addition to requiring additional time, writing and punching data cards risks additional errors and consumes time.

The only way to avoid the time lost by punching, computing and checking errors would be a linear programming model that has already been punched and tested. Such a model would also eliminate much of the need for staff time to set up the necessary input-output data.

THE CASE FARM

The case farm selected for this study was not an actual situation, but rather was synthesized from several actual farm situations. The case farm is composed of a total of 360 acres. Out of the total acreage, 35 acres are in farmstead, roads and waste and 75 acres are in permanent pasture. The 250 acres of tillable land are divided into two basic productivity levels. The higher productivity soil is composed of 200 acres capable of maintaining row crops three years out of five. The remaining 50 acres of cropland can maintain row crops only one year out of five. Out of the total of 250 tillable acres, therefore, a maximum of 130 acres can be in row crops during any one year.

The Soil Association

The Ida Monona soil association was chosen for the case farm. These soils are found primarily in western Iowa.[1] Because this soil type has rather limited production potential and includes a relatively large amount of permanent pasture, the question may be raised why a more productive soil was not selected.

It was felt that, given the objectives of this study, a model containing several land classes with restricted cropping use would be more desirable. If a model can be developed to consider these land use restrictions, a model to consider fewer restrictions, such as might be found in more productive soil associations, would certainly be feasible.

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[1]See Appendix A.

Table 2. Seasonal labor supply for the case farm

Season		Hours
Winter		930
December	200	
January	200	
February	200	
March	200	
April 1-15	130	
Spring		650
April 16-30	130	
May	260	
June	260	
Summer		690
July	230	
August	230	
September	230	
Fall		520
October	260	
November	260	

The Labor Supply

The labor supply on the case farm was chosen to be typical of the supply on farms of similar size. Operator labor averaged 230 hours per month. However, it was also assumed that the operator would be willing to work longer periods during planting and harvesting seasons. Therefore, the operator labor supply was set at 260 hours per month during the peak labor periods.

Labor and capital constraints were formed for seasonal production periods. Table 2 indicates the seasonal labor supply used for this study. Any hired labor used on the farm was available at an hourly rate of $1.50.

The Capital Coefficients

The capital coefficients for the case farm reflected all cash expenses to the farm business. The coefficients were also allocated into the same seasonal pattern as labor requirements. An annual requirement for breeding stock was also included for livestock raising activities.

If, in any production period, an activity required cash expenses, that amount of expense was defined as a capital requirement. If in the succeeding period additional expenses were required, only the additional expenses were defined as a capital requirement in the succeeding period. Similarly, when the activity was concluded, no additional coefficients were defined for succeeding periods.

It was assumed that the case farm had adequate grain storage and livestock facilities to accommodate the activities at any level at which they might enter. Therefore, no capital coefficients were specified for facilities other than the amount required for repairs to maintain them. Likewise, an adequate line of machinery was assumed to be available. The only machinery costs included in the capital coefficients were repairs and operating costs.

Cash Accounting System

To assist in better describing the solutions obtained from linear programming, a system of cash accounting was defined. All capital expenses and receipts were divided into three categories--breeding stock investment, livestock purchases and receipts, and basic production expenses and receipts.

Investments in breeding stock were separated from livestock purchases because, in an ongoing business, breeding stock may be raised rather than purchased. Nevertheless, a definite investment in parent stock would be required to start production at a given time. In addition, breeding stock represent a relatively liquid asset. A single-value requirement was defined for each activity that included breeding stock.

The second category of capital accounts was livestock purchases and receipts. All livestock purchased and fed for resale required a cash outlay during the season purchased. By specifying the seasonal purchase cost of the livestock, the output report would list the seasonal cash outlay for all livestock purchases. Similarly, livestock receipts were credited to the capital account during the season of sale.

The third category of capital accounts--production expenses and receipts--included such items as seed, fertilizer, fuel, repairs and other variable costs related to the cropping program, as well as supplement costs, veterinary and medical expenses, and other variable expenses related to livestock production. Cash rental charges for land and hourly wages for hired labor were also defined as production expenses. Production receipts included all crop sales as well as rent payments from pasture land.

The output report would include a description of total breeding stock investment, seasonal livestock purchases and sales, and seasonal production expenses and crop receipts. It will be shown later how the cash accounting system was used with crop and livestock marketing activities.

Table 3. Crop rotation alternatives

Class I Land	
	C-SB-C-O-M
	C-C-C-O-M
	C-C-O-M-M
	C-C-O-M
Class II Land	
	C-O-M-M-M

Cropping Activities

The crop activities considered were defined in a crop rotation framework. Four different crop rotations were considered for the 200 acres of Class I productive land. Only one crop rotation was defined for the 50 acres of Class II land. To account for total crop production and to assist in accounting for the cash flow within the business, the crop activities included all variable costs for growing and harvesting the crops. However, the crops produced were not sold from each activity but rather were listed in a transfer row from which they could be either fed to livestock or sold at the market price. The crop growing and harvesting activities, therefore, all have negative net prices. The latter reflect the total variable costs associated with each activity. The crop rotation alternatives are listed in Table 3.

The soybean yield was assumed to be 28 bushels per acre, and corn yields were assumed to be 80 bushels per acre for the Class I land and 70 bushels per acre for the Class II land. Oat yields were assumed to be 50 bushels and 40 bushels per acre, respectively. Hay yields were three tons per acre and decreased 0.2 tons per acre for each additional year the land

Table 4. Production coefficients for crop activities[a]

	C-SB-C-O-M	C-C-C-O-M	C-C-O-M	C-C-O-M-M	C-O-M-M-M
Land Class	I	I	I	I	II
Yields:					
Corn (bu.)	160	240	160	160	70
Soybeans (bu.)	28	0	0	0	0
Oats (bu.)	50[b]	50[b]	50[b]	50[b]	40[b]
Meadow (tons hay equiv.)	3.0	3.0	3.0	5.8	8.4
Winter variable costs	$ 7.50	$ 7.50	$ 5.50	$ 5.50	$ 3.50
Spring variable costs	64.20	61.90	47.10	50.10	38.30
Summer variable costs	7.90	9.35	7.90	8.90	8.45
Fall variable costs	44.40	61.30	38.20	38.20	18.10
Total variable costs	$124.00	$140.05	$98.70	$102.70	$68.35
Winter labor required (hours)	0.0	0.0	0.0	0.0	0.0
Spring labor required (hours)	9.0	10.8	7.7	7.7	4.6
Summer labor required (hours)	6.2	5.1	4.9	5.4	5.7
Fall labor required (hours)	7.3	8.6	5.9	5.9	3.2
Total labor required (hours)	22.5	24.5	18.5	19.0	13.5

[a]Source (11,14,20,24).

[b]Two bushels of oats is assumed to equal one bushel of corn equivalent.

remained in meadow. Table 4 lists the production coefficients for the cropping activities.

Two additional crop activities involved crop harvesting.[1] One activity was a corn silage harvesting activity that, in terms of costs and labor inputs, transferred corn grain out of storage and into corn silage. The activity does not realistically describe the physical production methods, but it is mathematically correct. The second activity was a hay baling activity, since the hay activity listed in Table 4 is only a growing activity.

The model was also constructed to allow for either renting additional crop or pasture land or renting out unused rotated or permanent pasture land at prevailing cash rental rates.

The Livestock Activities

The livestock enterprises considered in this model included beef cows, dairy cows, beef feeding and hog farrowing and/or feeding. One beef cow activity was considered, two dairy cow activities differing only in the feed rations used, seven beef feeding activities, two hog farrowing activities differing only in the farrowing periods, and six hog feeding activities differing only in their timing. The production coefficients for these livestock activities are given in Table 5.

Like the cropping activities, the livestock activities provide for neither the purchasing nor selling of livestock. Rather, only the variable production costs associated with that enterprise enter the C-row value.

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[1] See Appendix B.

Table 5. Production coefficients for livestock activities[a]

Ration	Dairy cow Grain and hay	Dairy cow Silage, grain and hay	Beef cow Hay and pasture
Production	11,000 lbs. milk $ 65.00 beef income	11,000 lbs. milk $ 65.00 beef income	90% calf crop 18% saved for replacement steers @ 450#, hfrs. @ 420#
Breeding stock investment	490.00	490.00	$294.57
Winter variable costs	54.00	57.00	8.75
Spring variable costs	21.00	21.50	4.42
Summer variable costs	27.00	27.00	5.58
Fall variable costs	24.00	25.50	2.25
Total variable costs	$126.00	$131.00	$ 21.00
Winter labor required	30.4	30.4	3.5
Spring labor required	14.6	14.6	3.0
Summer labor required	17.2	17.2	1.5
Fall labor required	12.8	12.8	0.5
Total labor required	75.0	75.0	8.5
Feed required			
Corn equiv. (bu.)	65.0	45.0	2.0
Corn silage (tons)	0.0	7.7	0.0
Hay (tons)	6.0	3.6	1.8
Pasture (tons hay equiv.)	2.0	2.0	3.8

[a]Source (5,14,21,24).

Table 5 (Continued)

Ration	Yearling steer Grain & hay	Yearling steer Silage, grain & hay	Steer calf Grain & hay	Steer calf Silage, grain & hay
Purchase grade and weight	Ch. 635	Ch. 635	Ch. 450	Ch. 450
Sale grade and weight	Ch. 1150	Ch. 1200	Ch. 1050	Ch. 1075
Purchase date	Oct. 1	Oct. 1	Nov. 1	Nov. 1
Sale date	July 1	Aug. 1	Oct. 1	Nov. 1
Winter variable costs	$10.90	$11.40	$ 3.05	$ 3.05
Spring variable costs	3.75	4.25	10.75	10.75
Summer variable costs	0.00	0.75	4.20	4.95
Fall variable costs	5.05	5.55	5.70	6.45
Total variable costs	$19.70[b]	$21.95[b]	$23.70[b]	$25.20[b]
Winter labor (hours)	4.2	4.2	4.2	4.2
Spring labor (hours)	2.2	2.2	2.1	2.1
Summer labor (hours)	0.0	0.8	1.7	1.7
Fall labor (hours)	1.6	1.6	1.0	1.8
Total labor (hours)	8.0	8.8	9.0	9.8
Feed requirements				
Corn equiv. (bu.)	60.0	40.0	62.0	40.0
Corn silage (tons)	0.0	4.25	0.0	4.0
Hay (tons)	1.0	0.3	0.8	0.3
Pasture (tons hay equiv.)	0.0	0.0	0.0	0.0

[b] All net prices in programming matrix include value of death loss based on purchase price.

Table 5 (Continued)

Ration	Steer calf Long term pasture	Yearling steer Grain & hay	Yearling steer Silage, grain & hay	Heifer calf Grain & hay
Purchase grade and weight	Ch. 450	Com. 650	Com. 650	Ch. 420
Sale grade and weight	Ch. 1125	Good 1025	Good 1085	Ch. 870
Purchase date	Oct. 1	Oct. 1	Oct. 1	Nov. 1
Sale date	Dec. 1	April 1	May 1	Aug. 1
Winter variable costs	$ 5.65	$ 8.35	$10.35	$10.55
Spring variable costs	4.15	0.00	0.00	4.80
Summer variable costs	2.00	0.00	0.00	1.50
Fall variable costs	7.55	6.60	7.60	3.75
Total variable costs	$19.35[b]	$14.95[b]	$17.95[b]	$20.60[b]
Winter labor required (hours)	4.2	4.2	4.2	4.2
Spring labor required (hours)	2.3	0.0	0.4	2.2
Summer labor required (hours)	2.0	0.0	0.0	0.8
Fall labor required (hours)	2.5	1.6	1.6	1.0
Total labor required (hours)	11.0	5.8	6.2	8.2
Feed requirements				
Corn equiv. (bu.)	46.0	42.0	30.0	47.0
Corn silage (tons)	0.0	0.0	3.25	0.0
Hay (tons)	1.2	0.8	0.25	0.8
Pasture (tons hay equiv.)	1.3	0.0	0.0	0.0

Table 5 (Continued)

	Sow and two litters			
Farrowing dates	December and June		February and August	
Breeding stock investment	$77.00		$77.00	
Average litter size	7.5 pigs		7.5 pigs	
Average market weight	40 lbs.		40 lbs.	
Marketing dates	February	6.5 pigs[c]	April 1	6.5 pigs[c]
	August	7.5 pigs	Oct. 1	7.5 pigs
	August	sow @ 400 lbs.	Oct. 1	sow @ 400 lbs.
Winter variable costs	$23.37		$35.30	
Spring variable costs	33.55		15.75	
Summer variable costs	12.35		29.10	
Fall variable costs	21.43		10.55	
Total variable costs	$90.70		$90.70	
Winter labor required (hours)	11.7		11.7	
Spring labor required (hours)	5.8		1.3	
Summer labor required (hours)	4.5		9.0	
Fall labor required (hours)	1.0		1.0	
Total labor required (hours)	23.0		23.0	
Feed requirements				
Corn equiv. (bu.)	64.0		64.0	
Pasture (tons hay equiv.)	0.5		0.5	

[c]One gilt saved for replacement.

Table 5 (Continued)

	Feeder pigs purchased and fed to market weight					
Purchase date	Dec. 1	Feb. 1	April 1	June 1	Aug. 1	Oct. 1
Purchase weight	40	40	40	40	40	40
Sale date	April 1	June 1	Aug. 1	Oct. 1	Dec. 1	Feb. 1
Sale weight	220	220	220	220	220	220
Winter variable costs	$7.175	$4.815	$0.00	$0.00	$0.00	$3.325
Spring variable costs	0.00	2.36	5.74	2.40	0.00	0.00
Summer variable costs	0.00	0.00	1.435	4.775	3.85	0.00
Fall variable costs	0.00	0.00	0.00	0.00	3.325	3.85
Total variable costs	$7.175	$7.175	$7.175	$7.175	$7.175	$7.175
Winter labor required	1.1	0.65	0.15	0.0	0.0	0.45
Spring labor required	0.0	0.45	0.75	0.35	0.0	0.0
Summer labor required	0.0	0.0	0.2	0.75	0.65	0.0
Fall labor required	0.0	0.0	0.0	0.0	0.45	0.65
Total labor required	1.1	1.1	1.1	1.1	1.1	1.1
Feed requirements						
Corn equiv. (bu.)	11.4	11.4	11.4	11.4	11.4	11.4

Table 6. Crop and livestock marketing activities[a]

Activity name	Unit	Price
Crops		
Bushels of corn sold	bushel	$ 1.20
Bushels of corn bought	bushel	-1.30
Bushels of soybeans sold	bushel	2.70
Tons of hay sold	ton	18.00
Tons of hay bought	ton	-20.00
Acres of cropland rented	acre	-20.00
Acres of rotated pasture rented out	acre	15.00
Acres of rotated pasture acquired	acre	-15.00
Acres of permanent pasture rented out	acre	6.65
Livestock		
Cwt. choice steer calf bought	cwt.	-30.50
Cwt. choice steer calf sold	cwt.	28.75
Cwt. choice fed steer sold in fall	cwt.	27.50
Cwt. choice yearling feeder steer bought	cwt.	-27.00
Cwt. choice fed steer sold in summer	cwt.	27.50
Cwt. choice long fed steer sold in winter	cwt.	27.50
Cwt. common yearling feeder steer bought	cwt.	-24.00
Cwt. good fed steer sold	cwt.	25.50
Cwt. choice heifer calf bought	cwt.	-28.00
Cwt. choice heifer calf sold	cwt.	27.00
Cwt. choice fed heifer sold	cwt.	25.50
Cwt. milk sold	cwt.	4.50

[a]Source (24).

Table 6 (Continued)

Activity name	Unit	Price
Cwt. feeder pigs bought in October	cwt.	$-36.00
Cwt. feeder pigs sold in October	cwt.	36.00
Cwt. feeder pigs bought in December	cwt.	-36.00
Cwt. feeder pigs bought in February	cwt.	-36.00
Cwt. feeder pigs sold in February	cwt.	36.00
Cwt. feeder pigs bought in April	cwt.	-36.00
Cwt. feeder pigs sold in April	cwt.	36.00
Cwt. feeder pigs bought in June	cwt.	-36.00
Cwt. feeder pigs bought in August	cwt.	-36.00
Cwt. feeder pigs sold in August	cwt.	36.00
Cwt. market hogs sold in winter	cwt.	19.00
Cwt. market hogs sold in spring	cwt.	19.00
Cwt. market hogs sold in summer	cwt.	19.00
Cwt. market hogs sold in fall	cwt.	19.00

For the beef cow activity, the calves produced were offered for sale or could be fed to market weight. Milk from dairy activities was offered for sale at the market price minus marketing costs. Likewise, for the beef and hog feeding activities, the purchasing and selling activities were separate from the feeding activities. All livestock marketing activities were in terms of hundred weight units and included the capital expenses or receipts discussed earlier. The complete list of marketing activities and their respective prices are listed in Table 6.

The marketing activities were defined separately from the growing and feeding activities so that 1) variable price programming for livestock activities would be facilitated since only the net price of the marketing activity would be changed from one solution to the next, and 2) the shadow prices (i.e., estimates of marginal value products and income penalties) would be reported in terms of commonly used marketing units.

Accounting Activities

Along with the marketing activities, other activities were added to give a fuller description of what the computed solution of the farm business organization actually contained. In terms of linear programming computation, these accounting activities could be thought of as purchasing activities with a zero net price. In recording the use of hired labor and capital, the activities purchased the inputs at appropriate wage and interest rates. Aside from activities that actually purchased an input, the accounting activities served no purpose in the computational procedures other than to make the printed output more informative. The list of accounting activities is given in Table 7.

Table 7. Accounting activities

Activity name	Unit	Price
Hours of winter operator labor used	hour	$0.00
Hours of spring operator labor used	hour	0.00
Hours of summer operator labor used	hour	0.00
Hours of fall operator labor used	hour	0.00
Hours of winter labor hired	hour	-1.50
Hours of spring labor hired	hour	-1.50
Hours of summer labor hired	hour	-1.50
Hours of fall labor hired	hour	-1.50
Total cash expense and livestock investment	$1.00	0.00
Winter cash expenditures	1.00	-0.07
Spring cash expenditures	1.00	-0.07
Summer cash expenditures	1.00	-0.07
Fall cash expenditures	1.00	-0.07
Breeding stock investment	1.00	-0.06
Winter livestock purchases	1.00	-0.07
Spring livestock purchases	1.00	-0.07
Summer livestock purchases	1.00	-0.07
Fall livestock purchases	1.00	-0.07
Winter cash receipts	1.00	0.00
Spring cash receipts	1.00	0.00
Summer cash receipts	1.00	0.00
Fall cash receipts	1.00	0.00
Winter livestock receipts	1.00	0.00
Spring livestock receipts	1.00	0.00
Summer livestock receipts	1.00	0.00
Fall livestock receipts	1.00	0.00
Acres of corn	acre	0.00
Acres of soybeans	acre	0.00
Acres of oats	acre	0.00
Acres of meadow	acre	0.00

Table 7 (Continued)

Activity name	Unit	Price
Number of dairy cows	head	0.00
Number of beef cows	head	0.00
Number of cattle fed	head	0.00
Number of litters of pigs	litters	0.00
Number of hogs fed	head	0.00
Bushels of corn fed	bushel	0.00
Tons of corn silage harvested	ton	-0.95
Tons of hay baled	ton	-6.65
Tons of meadow used as pasture	ton	0.00

The accounting activities were combined with a relatively new feature, the bounding device, of the computer program. Previously, no simple method existed to limit an individual activity within the model. The new feature allows the planner to place a minimum or maximum restraint on each activity without specifying a separate restraint row for each restraint imposed.

When this feature is combined with the accounting activities, the planner can specify nearly all of the restraints and desired enterprise levels merely by specifying an upper or lower bound on each activity.

As an example, the planner might desire that the final plan contain exactly 50 head of fed cattle, and that 20 of those should be steer calves on a silage ration. The planner would then specify an equality or fixed bound of 20 on the steer calf activity with the silage ration. The computing routine would first choose the 20 steer calves, then select the most profitable of all of the remaining fed beef activities to meet the requirement of the remaining 30 head.

With the availability of the bounding feature on each activity, it then becomes possible to use the linear programming model for partial optimization or complete budgeting.

The level of each activity can be specified in such a manner that no choices for optimization are left to the computational procedure. The advantage of doing the budgeting within the linear programming framework is that, unlike usual budgeting techniques, the marginal value product of resources and the income penalties of activities not in the solution are also computed.

Fixed Costs

Because one of the purposes in constructing the model was to provide a detailed description of the computed solution, it was decided to include the fixed costs for the farm in the model. Since fixed costs cannot be included with a production activity, the bounding feature of the model permitted the use of separate fixed cost activities. With a net price of $-1.00, the fixed cost activities are simply bounded at the same upper and lower bound as the level of the fixed costs. Where all fixed costs are accounted for in the model, the computed value of the final solution, whether budgeted or optimized, becomes an estimate of net farm income. If the planner desired, he could also include additional fixed cost activities allowing for family living expenses. Income taxes, however, would need to be omitted or only roughly approximated. If income taxes were debited, the value of the computed solution would then be an estimate of the increment in capital available to start the next production period.

The Annual Repeating Cycle

Several possibilities for defining the planning periods are available to a farm planner for use in linear programming. Traditionally, budgeting and linear programming applications to farm planning have used the one-year repeating cycle planning period. With this form of planning period, the optimum solution is reached immediately and, until some resource restriction changes, the organization of the farm is assumed to remain the same.

If one were to start with a beginning farmer and allow his business to change as the supply of resources increased, the single-year repeating cycle could be used if the increase in capital from one solution were made available as a resource for the next problem. This method has its faults, however. If the increase in capital becomes irregular or large, the optimum business organization may shift erratically from one solution to the next, making the transitions in business organization difficult to interpret for an actual farm situation.

The computational procedure for more understandable business organization transitions is that of dynamic programming. This form of programming allows for multi-production period or multi-year planning periods in which the closing business organization is transferred directly to the beginning of the succeeding period. Such a programming model can describe more fully the transitions that occur as the business expands towards an optimum goal.

However, the dynamic model also requires a considerably larger input-output matrix to allow for the multi-period planning. For a dynamic model, defining and storing the amount of data necessary for the kind of master model intended in this study would require many times the effort needed for the present desired model. It was decided that at this time, the additional effort was not worth the additional benefit gained.

The planning model used, therefore, was the annual repeating cycle model. No attempt was made to estimate a value of beginning liquid assets. Rather, all capital used was simply accounted within the model. No attempt was made to allow for capital accumulation during the production cycle. Instead, all receipts and expenses were computed independently in the period in which they occurred. In other words, no capital restraints were specified.

One problem encountered with the repeating cycle model is that there is no beginning and no end. Because livestock and crop activities overlap a twelve month period, there is no time when all production ceases. This situation corresponds to the actual circumstances on a typical grain and livestock farm.

PRESENTATION OF RESULTS

The demonstration model was applied in four different situations on the case farm to test its potential use. An optimum organization of enterprises was sought first with labor, land and livestock facilities as the resource constraints. This optimization is referred to hereafter as Situation A. The only change made for the second optimization, hereafter labeled Situation B, was to raise feeder pig prices. The third and fourth optimizations, labeled Situation C and D respectively, were partial optimization problems in which hogs or beef cattle were either specified at fixed levels or not considered.

The Printed Output

The tables of results given in this section illustrate the format of the printed output that ought to be used. This format is not now available with the linear programming routine being used at Iowa State University (13). However, because the format in which output is presented in this thesis had been developed for a linear programming routine previously used by members of the farm management staff, the assumption was made that a similar format could and would be developed for the present routine.

Situation A

As stated above, the first situation analyzed was one in which labor, land, and livestock facilities were resource constraints. The resource and facility constraints for Situation A are given in Table 8. All of the constraints unique to Situation A were implemented by placing upper bounds on

Table 8. Resource and facility constraints for Situation A

B-column constraints	Level	Type
R01 Hours of winter operator labor available	930.0	Maximum
R02 Hours of spring operator labor available	650.0	Maximum
R03 Hours of summer operator labor available	690.0	Maximum
R04 Hours of fall operator labor available	520.0	Maximum
R21 Acres of Class I land owned	200.0	Maximum
R22 Acres of Class II land owned	50.0	Maximum
R34 Tons hay equivalent of permanent pasture owned	94.0	Maximum
Activity Bounds		
P005 Hours of winter labor hired	0.0	Upper bound
P006 Hours of spring labor hired	650.0	Upper bound
P007 Hours of summer labor hired	0.0	Upper bound
P008 Hours of fall labor hired	520.0	Upper bound
P036 Number of dairy cows	20.0	Upper bound
P037 Number of beef cows	50.0	Upper bound
P038 Number of cattle fed	150.0	Upper bound
P039 Number of litters of pigs	80.0	Upper bound

Table 8 (Continued)

B-column constraints	Level	Type
P040 Number of hogs fed	560.0	Upper bound
P056 Tons of hay sold	0.0	Upper bound
P058 Acres of cropland rented	120.0	Upper bound
P168 Sow and two litters farrowed in December-June	20.0	Upper bound
P169 Sow and two litters farrowed in February-August	20.0	Upper bound
P180 Feeder pigs started in December	150.0	Upper bound
P181 Feeder pigs started in February	150.0	Upper bound
P182 Feeder pigs started in April	150.0	Upper bound
P183 Feeder pigs started in June	150.0	Upper bound
P184 Feeder pigs started in August	150.0	Upper bound
P185 Feeder pigs started in October	150.0	Upper bound
P200 Real estate taxes	1250.0	Fixed bound
P201 Machinery depreciation	1900.0	Fixed bound
P202 Building depreciation	850.0	Fixed bound

activities rather than specifying B-column, or right-hand-side, elements.

It was assumed that capital would not be a limiting factor, given the other resource constraints. Similarly, it was assumed that labor would or could be hired only during the spring and fall seasons. The assumptions for labor were not meant to approximate a realistic labor supply, but rather were meant to test the potential size of the business with additional labor during the periods of typical labor shortage. The amount of additional cropland that could be rented was restricted to the amount the operator could manage with his existing machinery inventory.

The livestock facility restrictions were selected to approximate the buildings commonly found on many farms of similar size. The seasonal restrictions were placed on hog farrowing and feeding activities to keep hog production within the facility limitations during each season.

The optimum solution to Situation A is given in Table 9. The total computation time required for this optimization was 1.27 minutes.

The optimum solution shown in the table indicates that all of the operator labor was utilized, and labor was hired in both spring and fall. Since available hired labor was not fully used in the spring and fall, however, the report indicates that labor was not restricting in those two seasons. By contrast, Section 3 shows that the marginal value product of winter and summer labor is $3.63 and $5.23 respectively.

Section 1 of the output report shows that a total of $54,875.14 was required for cash expense and livestock investment. Seasonal cash expenditures, livestock purchases, and livestock receipts describe the seasonal cash flow. By subtracting all cash expenditures within a season, excluding the yearly breeding stock investment, from all cash receipts, it can be

Table 9. Optimum solution to farm Situation A

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P001 Hours winter operator labor used	930.00	0.00
P002 Hours spring operator labor used	650.00	0.00
P003 Hours summer operator labor used	690.00	0.00
P004 Hours fall operator labor used	520.00	0.00
P006 Hours spring labor hired	498.89	-1.50
P008 Hours fall labor hired	372.33	-1.50
P009 Total cash expense and livestock investment	54,785.14	0.00
P010 Winter cash expenditures	7,701.92	-0.07
P011 Spring cash expenditures	5,863.06	-0.07
P012 Summer cash expenditures	1,914.45	-0.07
P013 Fall cash expenditures	5,604.05	-0.07
P014 Breeding stock investment	8,493.95	-0.06
P015 Winter livestock purchases	2,059.44	-0.07
P016 Spring livestock purchases	2,160.00	-0.07
P018 Fall livestock purchases	20,988.27	-0.07
P023 Winter livestock receipts	52,676.25	0.00
P024 Spring livestock receipts	6,270.00	0.00
P025 Summer livestock receipts	7,356.75	0.00
P026 Fall livestock receipts	1,107.78	0.00
P030 Acres of corn	138.43	0.00
P032 Acres of oats	54.21	0.00
P033 Acres of meadow	78.43	0.00
P037 Number of beef cows	28.55	0.00
P038 Number of cattle fed	150.00	0.00
P039 Number of litters of hogs	2.15	0.00
P040 Number of hogs fed	458.06	0.00
P052 Bushels of corn fed	12,247.73	0.00
P055 Tons of hay baled	17.97	-6.65
P057 Tons of hay bought	213.43	-20.00

Table 9 (Continued)

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P058 Acres of cropland rented	21.06	-20.00
P063 Tons of meadow used as pasture	209.51	0.00
P070 Cwt. choice steer calf bought	617.32	-30.50
P075 Cwt. choice steer long fed sold in winter	1,687.50	27.50
P079 Cwt. choice heifer calf sold	28.55	27.00
P080 Cwt. choice fed heifer sold	39.98	25.50
P086 Cwt. feeder pigs bought in October	60.00	-36.00
P089 Cwt. feeder pigs bought in February	57.21	-36.00
P091 Cwt. feeder pigs bought in April	60.00	-36.00
P096 Cwt. market hogs sold in winter	330.00	19.00
P097 Cwt. market hogs sold in spring	330.00	19.00
P098 C t. market hogs sold in summer	333.55	19.00
P099 Cwt. market hogs sold in fall	17.73	19.00
P102 5 acre rotation of C-C-C-O-M on Land I	42.11	-140.05
P105 5 acre rotation of C-O-M-M-M on Land II	12.11	-68.35
P140 Beef cow on pasture	28.55	-21.00
P150 Choice steer calf long fed on pasture	150.00	-22.10
P168 Sow and two litters farrowed in December & June	1.07	-90.70
P181 Feeder pig started in February	150.00	-7.175
P182 Feeder pig started in April	150.00	-7.175
P184 Feeder pig started in August	8.06	-7.175
P185 Feeder pig started in October	150.00	-7.175
P200 Real estate taxes	1,250.00	-1.00
P201 Machinery depreciation	1,900.00	-1.00
P202 Building depreciation	850.00	-1.00

Table 9 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P005 Hours winter labor hired	-2.02	-1.50
P007 Hours summer labor hired	-3.62	-1.50
P017 Summer livestock purchases	0.04	-0.07
P019 Winter cash receipts	0.0	0.0
P020 Spring cash receipts	0.0	0.0
P021 Summer cash receipts	0.0	0.0
P022 Fall cash receipts	0.0	0.0
P031 Acres of soybeans	0.0	0.0
P036 Number of dairy cows	0.0	0.0
P050 Bushels of corn sold	0.13	1.20
P051 Bushels of corn bought	0.06	-1.30
P053 Tons of corn silage harvested	0.0	-0.95
P054 Bushels of soybeans sold	0.53	2.70
P056 Tons of hay sold	3.40	18.00
P060 Acres rotated pasture rented out	0.57	15.00
P061 Acres rotated pasture acquired	0.48	-15.00
P062 Acres permanent pasture rented out	0.30	6.65
P071 Cwt. choice steer calf sold	3.88	28.75
P072 Cwt. choice yearling steer sold in fall	2.43	27.50
P073 Cwt. choice yearling steer bought	0.00	-27.00
P074 Cwt. choice yearling steer sold in summer	1.81	27.50
P076 Cwt. common yearling steer bought	0.00	-24.00
P077 Cwt. good yearling steer sold	2.10	25.50
P078 Cwt. choice heifer calf bought	2.96	-28.00
P084 Cwt. milk sold	0.67	4.50
P087 Cwt. feeder pigs sold in October	2.52	36.00

Table 9 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P088 Cwt. feeder pigs bought in December	0.0	-36.00
P090 Cwt. feeder pigs sold in February	2.52	36.00
P092 Cwt. feeder pigs sold in April	2.52	36.00
P093 Cwt. feeder pigs bought in June	0.0	-36.00
P094 Cwt. feeder pigs bought in August	0.0	-36.00
P095 Cwt. feeder pigs sold in August	0.97	36.00
P101 5 acre rotation of C-SB-C-O-M on Land I	0.0	-124.00
P103 4 acre rotation of C-C-O-M on Land I	19.63	-98.70
P104 5 acre rotation of C-C-O-M-M on Land I	50.16	102.70
P128 Dairy cow on grain and hay ration	0.0	-125.90
P129 Dairy cow on silage, grain and hay ration	11.40	-130.90
P151 Choice steer calves on grain and hay ration	1.00	-26.44
P152 Choice steer calves on silage, grain and hay ration	0.00	-27.94
P153 Choice yearling steers on grain and hay ration	3.36	-21.41
P154 Choice yearling steers on silage, grain and hay ration	0.0	-23.66
P155 Common yearling steers on grain and hay ration	3.96	-16.51
P156 Common yearling steers on silage, grain and hay ration	0.00	-19.51
P157 Choice heifer calves on grain and hay ration	31.70	-22.94
P169 Sow and two litters farrowed in February and August	4.66	-90.70
P180 Feeder pigs started in December	0.49	-7.175
P183 Feeder pigs started in June	0.98	-7.175

Table 9 (Continued)

Section 3

Restrictions that are limiting the optimum plan	Marginal value product
R01 Hours winter operator labor available	3.63
R02 Hours spring operator labor available	1.60
R03 Hours summer operator labor available	5.23
R04 Hours fall operator labor available	1.60
R13 Winter cash expenses	0.07
R14 Spring cash expenses	0.07
R15 Summer cash expenses	0.07
R16 Fall cash expenses	0.07
R17 Winter livestock purchases	0.07
R18 Spring livestock purchases	0.07
R19 Summer livestock purchases	0.03
R20 Fall livestock purchases	0.07
R21 Acres land quality I	32.53
R22 Acres land quality II	10.27
R29 Corn grain harvest transfer, bushel	1.33
R30 Corn silage transfer, ton	10.91
R31 Soybean transfer, bushels	3.23
R32 Standing meadow transfer, hay equiv. tons	5.56
R33 Hay transfer, tons	21.40
R34 Permanent pasture transfer, hay equiv. tons	5.56
R35 Feeding corn transfer, bushel	1.33
R38 Milk transfer, cwt.	5.17
R39 Choice steer calf feeder transfer, cwt.	32.64
R40 Choice yearling steer feeder transfer, cwt.	28.89
R41 Common yearling steer feeder transfer, cwt.	25.68
R42 Choice heifer calf feeder transfer, cwt.	27.00

Table 9 (Continued)

Section 3

Restrictions that are limiting the optimum plan	Marginal value product
R43 Summer choice fed beef transfer, cwt.	29.31
R44 Fall choice fed beef transfer, cwt.	29.93
R45 Spring good fed beef transfer, cwt.	27.60
R46 Choice fed heifer transfer, cwt.	25.50
R47 Winter choice fed beef transfer, cwt.	27.50
R50 Feeder pig transfer cwt. December	38.52
R51 Feeder pig transfer cwt. February	38.52
R52 Feeder pig transfer cwt. April	38.52
R53 Feeder pig transfer cwt. June	38.52
R54 Feeder pig transfer cwt. August	36.97
R55 Feeder pig transfer cwt. October	38.52
R56 Market hog transfer cwt. winter	19.00
R57 Market hog transfer cwt. spring	19.00
R58 Market hog transfer cwt. summer	19.00
R59 Market hog transfer cwt. fall	19.00
R68 Fed beef capacity, head	11.36
R84 Breeding stock investment	0.06
C Net farm income	14,313.75

shown that only in the fall season are the cash expenses greater than the cash receipts. Thus, if all capital for cash expenses and livestock purchases were borrowed, the interest payments would be less than the amount that is charged in the model because capital would be borrowed for less than the full year. It should be noted that all cash receipts to the business during the year came from livestock sales, indicating that all crops were fed to livestock. No corn was bought but more than 200 tons of hay were purchased. Twenty-one acres of additional cropland were rented.

The description of the cropping program indicates that corn production dominated the cropping system, given the rotation constraints for the land. From Section 2 of Table 9 the income penalty for (growing and) selling one bushel of soybeans is \$0.53. This indicates that with the crop coefficients assumed the sale price of soybeans must increase by \$0.53 per bushel before soybeans can begin to compete with corn production. The minimum competing sale price of soybeans is also found in Section 3 in the soybean transfer row.

Similarly, there is an income penalty for either buying or selling corn. The income penalty for selling corn is \$0.13 per bushel. Therefore, the sale price of corn must increase by that amount before it becomes competitive with feeding the corn to livestock. One may conclude, therefore, that the marginal feeding value of corn is \$1.33 per bushel. Such a value, however, is greater than the purchase price of \$1.30 for corn, and yet there is a \$0.06 income penalty per bushel for buying corn. The apparent discrepancy is explained by the fact that there is a seven percent interest charge on all production expenses. This increases the cost of purchasing and feeding a bushel of corn to \$1.39. Subtracting the \$1.33 marginal feeding value of corn leaves an income penalty of $0.06 per bushel.

The marginal value product of both Class I and Class II land is given in Section 3 of the output report. It should be noted that the marginal value product of the Class I land is more than three times that of the Class II land. The farm planner could use these values to estimate the value of an additional acre of either class of land to the operator. By subtracting the annual fixed costs associated with each class of land and capitalizing the remainder at the desired interest rate, the break even purchase price could be determined for an additional acre of each class of land.

The advantages of the use of marketing activities is clearly evident in the description of the livestock program. The marketing activities in Section 1 account for the total weight of each type and grade of livestock bought and sold. Of more importance, however, are the marketing activities in Section 2.

The first livestock marketing activity reported in Section 2 is P071 (selling choice steer calves). The income penalty attached to this activity is $3.88 per hundredweight. The income penalty indicates the reduction in net income that would have occurred if the operator had sold his steer calves after having once bought them. The reduction in net income is also the amount that must be added to the present selling price of choice steer calves to bring the selling price of choice steer calves in line with the buying price. As with the income penalty for buying corn, the income penalty for selling calves is composed of the difference in the selling and buying price and the interest charge on the purchase cost.

The income penalties for the sale of choice fed steers in the summer or fall indicate the relative disadvantage of the two feeding systems associated with those two seasons. Although only one cattle feeding activity entered at the maximum level, Section 3 indicates that the marginal value product of feeding space for an additional steer is $11.36.

The income penalty for selling 100 pounds of milk is $0.67. Even though there is no income penalty associated with one of the dairying activities, the $0.67 indicates that an increase of this amount in the price of milk would be necessary to make either of the dairying activities competitive. The minimum price of milk to make dairying competitive is then shown in the milk transfer row in Section 3.

Stated another way, the income penalty for milk sales indicates that with cows producing at the 11,000 pounds level, the income penalty per cow, on the margin, would be $73.70.

The optimum solution also indicated that only two litters of hogs would be farrowed, but that 458 pigs would be fed. All the pigs that were not raised were purchased as feeder pigs. Given the production coefficients, the price relationships favored purchasing feeder pigs rather than raising them. Section 3 of the output report indicates the marginal value product of feeder pigs in five out of six of the feeding periods is $38.52 per hundredweight.

Situation B

The case farm was optimized again, using the same resource and facility restriction as in Situation A, but the purchase price of feeder pigs was raised from $36.00 per hundredweight, or $14.40 per head, to test if more hogs would be farrowed instead of purchased. To have an impact on the profitability of purchasing feeder pigs the cost would need to be equal to or greater than $38.52 mentioned above. A price of $40.00 per hundredweight, or $16.00 per pig was selected.

The advantage of using marketing activities with conventional units of measurement is illustrated by the price adjustment in feeder pigs. To raise the price to $40.00 per hundredweight, the ten cards that included the prices for the sale or purchase of feeder pigs were taken from the input data deck and replaced with ten new cards specifying the $40.00 price. No additional budgeting was necessary. Had conventional activity definitions been used in the model or had the original C-row value on marketing activities been stated in terms other than hundredweights, more work would have been required. The optimum solution is shown in Table 10. The total computation time was 1.31 minutes.

The results from Situation B reveal some of the interdependencies that occur in farm planning which are difficult or impossible to illustrate with budgeting alone. The increase in the price of feeder pigs decreased the number of feeder pigs purchased, increased the number of litters farrowed, and decreased the total number of pigs fed to market.

Along with the changes in the hog enterprise, beef cows were eliminated and total cash expenses and livestock purchases were reduced more than $10,000. No additional cropland was rented, and the amount of labor hired was reduced. In addition, 33 acres of rotated pasture were rented out.

With all of the reductions in capital expenditures and livestock and crop production, net farm income was reduced by only $290.78. This small income reduction for Situation B suggests that the additional capital required for Situation A was returning very little above the 6 and 7% borrow-

Table 10. Optimum solution to farm Situation B

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P001 Hours winter operator labor used	930.00	0.00
P002 Hours spring operator labor used	650.00	0.00
P003 Hours summer operator labor used	690.00	0.00
P004 Hours fall operator labor used	520.00	0.00
P006 Hours spring labor hired	407.31	-1.50
P008 Hours fall labor hired	269.84	-1.50
P009 Total cash expense and livestock investment	43,617.73	0.00
P010 Winter cash expenditures	7,727.96	-0.07
P011 Spring cash expenditures	5,672.79	-0.07
P012 Summer cash expenditures	1,889.61	-0.07
P013 Fall cash expenditures	4,626.84	-0.07
P014 Breeding stock investment	1,359.66	-0.06
P016 Spring livestock purchases	1,753.37	-0.07
P018 Fall livestock purchases	20,587.50	-0.07
P019 Winter cash receipts	241.15	0.00
P020 Spring cash receipts	241.15	0.00
P021 Summer cash receipts	504.49	0.00
P023 Winter livestock receipts	47,768.18	0.00
P024 Spring livestock receipts	3,617.32	0.00
P025 Summer livestock receipts	8,542.64	0.00
P026 Fall livestock receipts	272.39	0.00
P030 Acres of corn	130.00	0.00
P032 Acres of oats	50.00	0.00
P033 Acres of meadow	70.00	0.00
P038 Number of cattle fed	150.00	0.00
P039 Number of litters of pigs	35.32	0.00
P040 Number of hogs fed	269.12	0.00
P050 Bushels of corn sold	401.91	1.20

Table 10 (Continued)

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P052 Bushels of corn fed	11,098.09	0.00
P057 Tons of hay bought	180.00	-20.00
P060 Acres of rotated pasture rented out	33.63	15.00
P063 Tons of meadow used as pasture	101.00	0.00
P070 Cwt. choice steer calf bought	675.00	-30.50
P075 Cwt. choice yearling steer long fed sold in winter	1,687.58	27.50
P091 Cwt. feeder pigs bought in April	48.70	-40.00
P095 Cwt. feeder pigs sold in August	39.94	40.00
P096 Cwt. market hogs sold in winter	71.68	19.00
P097 Cwt. market hogs sold in spring	190.38	19.00
P098 Cwt. market hogs sold in summer	373.94	19.00
P099 Cwt. market hogs sold in fall	14.34	19.00
P102 5 acre rotation of C-C-C-O-M on land I	40.00	-140.05
P105 5 acre rotation of C-O-M-M-M on land II	10.00	-68.35
P150 Choice steer calves long fed on pasture	150.00	-22.10
P168 Sow and two litters farrowed in December-June	13.31	-90.70
P169 Sow and two litters farrowed in February-August	4.34	-90.70
P181 Feeder pigs started in February	86.54	-7.175
P182 Feeder pigs started in April	150.00	-7.175
P185 Feeder pigs started in October	32.58	-7.175
P200 Real estate taxes	1,250.00	-1.00
P201 Machinery depreciation	1,900.00	-1.00
P202 Building depreciation	850.00	-1.00

Table 10 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P005 Hours winter labor hired	-3.74	-1.50
P007 Hours summer labor hired	-4.31	-1.50
P015 Winter livestock purchases	0.00	-0.07
P017 Summer livestock purchases	0.07	-0.07
P022 Fall cash receipts	0.00	0.00
P031 Acres of soybeans	0.00	0.00
P036 Number of dairy cows	0.00	0.00
P037 Number of beef cows	0.00	0.00
P051 Bushels of corn bought	0.19	-1.30
P053 Tons of corn silage harvested	0.00	-0.95
P054 Bushels of soybeans sold	0.17	2.70
P055 Tons of hay baled	0.69	-6.65
P056 Tons of hay sold	3.40	18.00
P058 Acres of cropland rented	5.75	-20.00
P061 Acres of rotated pasture acquired	1.05	-15.00
P062 Acres of permanent pasture rented out	0.05	6.65
P071 Cwt. choice steer calf sold	3.88	28.75
P072 Cwt. choice yearling steer sold in fall	2.33	27.50
P073 Cwt. choice yearling steer bought	0.00	-27.00
P074 Cwt. choice yearling steer sold in summer	1.68	27.50
P076 Cwt. common yearling steer bought	0.00	-24.00
P077 Cwt. good yearling steer sold	0.00	25.50
P078 Cwt. choice heifer calf bought	2.96	-28.00
P079 Cwt. choice heifer calf sold	0.00	27.00
P080 Cwt. choice fed heifer sold	3.56	25.50
P084 Cwt. milk sold	1.18	4.50
P086 Cwt. feeder pigs bought October	0.04	-40.00

Table 10 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P087 Cwt. feeder pigs sold October	2.48	40.00
P088 Cwt. feeder pigs bought December	0.00	-40.00
P089 Cwt. feeder pigs bought February	1.91	-40.00
P090 Cwt. feeder pigs sold February	0.61	40.00
P092 Cwt. feeder pigs sold April	2.52	40.00
P093 Cwt. feeder pigs bought June	0.00	-40.00
P094 Cwt. feeder pigs bought August	0.00	-40.00
P101 5 acre rotation of C-SB-C-O-M on land I	0.00	-124.00
P103 4 acre rotation of C-C-O-M on land I	16.68	-98.70
P104 5 acre rotation of C-C-O-M-M on land I	39.50	-102.70
P128 Dairy cow on grain and hay ration	0.00	-125.90
P129 Dairy cow on silage, grain and hay ration	10.84	-130.90
P140 Beef cow on pasture	0.00	-21.00
P151 Choice steer calves on grain and hay ration	0.00	-26.44
P152 Choice steer calves on silage, grain and hay ration	0.34	-27.94
P153 Choice yearling steers on grain and hay ration	1.79	-21.41
P154 Choice yearling steers on silage, grain and hay ration	0.00	-23.66
P155 Common yearling steers on grain and hay ration	24.87	-16.51
P156 Common yearling steers on silage, grain and hay ration	22.45	-19.51
P157 Choice heifer calves on grain and hay ration	0.00	-22.94
P180 Feeder pigs started in December	2.45	-7.175
P183 Feeder pigs started in June	1.57	-7.175
P184 Feeder pigs started in August	0.13	-7.175

Table 10 (Continued)

Section 3

Restrictions that are limiting the optimum plan	Marginal value product
R01 Hours winter operator labor available	5.35
R02 Hours spring operator labor available	1.60
R03 Hours summer operator labor available	5.92
R04 Hours fall operator labor available	1.60
R13 Winter cash expenses	0.07
R14 Spring cash expenses	0.07
R15 Summer cash expenses	0.07
R16 Fall cash expenses	0.07
R17 Winter livestock purchases	0.07
R18 Spring livestock purchases	0.07
R19 Summer livestock purchases	0.00
R20 Fall livestock purchases	0.07
R21 Acres land quality I	24.58
R22 Acres land quality II	6.72
R29 Corn grain harvest transfer, bushel	1.20
R30 Corn silage transfer, tons	10.50
R31 Soybean transfer, bushel	2.87
R32 Standing meadow transfer, hay equiv. tons	5.38
R33 Hay transfer, tons	21.40
R34 Permanent pasture transfer, hay equiv. tons	5.38
R35 Feeding corn transfer, bushel	1.20
R38 Milk transfer, cwt.	5.68
R39 Choice steer calf feeder transfer, cwt.	32.64

Table 10 (Continued)

Section 3

Restrictions that are limiting the optimum plan	Marginal value product
R40 Choice yearling steer feeder transfer, cwt.	28.89
R41 Common yearling steer feeder transfer, cwt.	25.68
R42 Choice heifer calf feeder transfer, cwt.	27.00
R43 Summer choice fed beef transfer, cwt.	29.18
R44 Fall choice fed beef transfer, cwt.	29.83
R45 Spring good fed beef transfer, cwt.	25.50
R46 Choice fed heifer transfer, cwt.	29.06
R47 Winter choice fed beef transfer, cwt.	27.50
R50 Feeder pig transfer, cwt. December	42.52
R51 Feeder pig transfer, cwt. February	40.61
R52 Feeder pig transfer, cwt. April	42.52
R53 Feeder pig transfer, cwt. June	42.52
R54 Feeder pig transfer, cwt. August	40.00
R55 Feeder pig transfer, cwt. October	42.48
R56 Market hog transfer, cwt. winter	19.00
R57 Market hog transfer, cwt. spring	19.00
R58 market hog transfer, cwt. summer	19.00
R59 Market hog trasnfer, cwt. fall	19.00
R67 Beef cow capacity, head	-1.03
R68 Fed beef capacity, head	9.21
R84 Breeding stock investment	0.06
C Net farm income	14,022.97

ing price.

The shift to hog farrowing increased the labor requirements during the winter and summer periods, forcing out beef cows and reducing crop production. The marginal value product of both winter and summer labor was also increased. In turn, the higher price on feeder pigs made baling hay unprofitable. Therefore, some rotated pasture was rented out while the hay requirements were purchased.

Two enterprises remained the same from Situation A to Situation B. First, corn production still dominated the cropping system on all land managed in Situation B. Second, the maximum number of long fed choice steer calves were still fed.

After optimizing the case farm under the two sets of price expectations in Situations A and B, two additional problems were specified in which either beef or hog production was fixed, and other enterprises were optimized within the added restraint of either a beef or hog activity forced in at a specified level. These two situations were intended to test the feasibility and usefulness of the model was a device for partial optimization.

Situation C

Situation C was specified to maximize beef production under given facility constraints and to eliminate all hog production on the case farm. All resource and enterprise constraints for Situation C are specified in Table 11.

The livestock production constraints were specified by bounding the livestock accounting activities. Hired labor was not restricted to avoid

Table 11. Resource and facility constraints for Situation C

All constraints are the same as those listed for Situation A except the following:

	Level	Type
P005 Hours of winter labor hired		No bounds
P006 Hours of spring labor hired		No bounds
P007 Hours of summer labor hired		No bounds
P008 Hours of fall labor hired		No bounds
P036 Number of dairy cows	0.0	Upper bound
P037 Number of beef cows	50.0	Fixed bound
P038 Number of cattle fed	150.0	Fixed bound
P039 Number of litters of pigs	0.0	Upper bound
P040 Number of hogs fed	0.0	Upper bound
P056 Tons of hay sold		No bounds
P058 Acres of cropland rented	0.0	Upper bound
P061 Acres of rotated pasture acquired	0.0	Upper bound

the possibility of an infeasibility or a result of the forced level of beef production. However, if hired labor and capital were both unrestricted, land rental had to be constrained to avoid an unbounded solution. Therefore, no opportunity to rent either crop or pasture land was provided. The results from Situation C are given in Table 12. Total computation time was 1.11 minutes.

In comparing the results of Situation C with Situation A, the net income is $2,614 less, but the total capital requirement is only $3,395 less. Very little summer labor and no winter is hired. About a third of the corn grain crop is sold, and some corn silage was harvested. All of the meadow was pastured rather than harvested for hay.

The restraints on hay and dairy production are shown in Section 2 to be costly under Situation C. Adding a dairy cow would have increased income by $87.98. Similarly, adding a litter of pigs would have increased income by $29.39. Section 3 repeats the same information and, in addition, indicates that adding another beef cow would have decreased income by $28.26. Forcing in all 50 beef cows in Situation C was not profitable.

Even with the emphasis on beef production, beef feeding facilities have a higher marginal value in Situation C than they do in Situation A.

In summarizing the partial optimization problem in Situation C, the most important comparison with Situation A is that the total resources required in Situation C are nearly as great as those in Situation A, but the income is considerably less.

Table 12. Optimum solution to farm Situation C

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P001 Hours winter operator labor used	930.00	0.00
P002 Hours spring operator labor used	650.00	0.00
P003 Hours summer operator labor used	690.00	0.00
P004 Hours fall operator labor used	520.00	0.00
P006 Hours spring labor hired	316.48	-1.50
P007 Hours summer labor hired	8.16	-1.50
P008 Hours fall labor hired	161.79	-1.50
P009 Total cash expense and livestock investment	51,389.82	0.00
P010 Winter cash expenditures	6,826.90	-0.07
P011 Spring cash expenditures	4,184.30	-0.07
P012 Summer cash expenditures	1,591.68	-0.07
P013 Fall cash expenditures	4,257.68	-0.07
P014 Breeding stock investment	14,733.78	-0.06
P015 Winter livestock purchases	0.14	-0.07
P018 Fall livestock purchases	19,795.32	-0.07
P019 Winter cash receipts	1,984.82	0.00
P020 Spring cash receipts	1,984.82	0.00
P023 Winter livestock receipts	25,708.22	0.00
P024 Spring livestock receipts	1.50	0.00
P025 Summer livestock receipts	23,867.21	0.00
P026 Fall livestock receipts	1,351.68	0.00
P030 Acres of corn	130.00	0.00
P032 Acres of oats	50.00	0.00

Table 12 (Continued)

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P033 Acres of meadow	70.00	0.00
P037 Number of beef cows	50.00	0.00
P038 Number of cattle fed	150.00	0.00
P050 Bushels of corn sold	3,308.04	1.20
P052 Bushels of corn fed	6,599.42	0.00
P053 Tons of corn silage harvested	284.44	-0.95
P057 Tons of hay bought	209.82	-20.00
P063 Tons of meadow used as pasture	204.04	0.00
P070 Cwt. choice steer calf bought	272.90	-30.50
P073 Cwt. choice yearling steer bought	424.88	-27.00
P074 Cwt. choice yearling steer sold in summer	802.92	27.50
P075 Cwt. choice yearling steer long fed sold in winter	934.76	27.50
P079 Cwt. choice heifer calf sold	50.00	27.00
P080 Cwt. choice fed heifer sold	70.02	25.50
P102 5 acre rotation of C-C-C-O-M on land I	40.00	-140.05
P105 5 acre rotation of C-O-M-M-M on land II	10.00	-68.35
P140 Beef cow on pasture	50.00	-21.00
P150 Choice steer calves long fed on pasture	83.09	-22.10
P154 Choice yearling steers on silage, grain and hay	66.91	-23.66
P200 Real estate taxes	1,250.00	-1.00
P201 Machinery depreciation	1,900.00	-1.00
P202 Building depreciation	850.00	-1.00

Table 12 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P005 Hours winter labor hired	1.60	-1.50
P016 Spring livestock purchases	0.07	-0.07
P017 Summer livestock purchases	0.03	-0.07
P021 Summer cash receipts	0.00	0.00
P022 Fall cash receipts	0.00	0.00
P031 Acres of soybeans	0.00	0.00
P036 Number of dairy cows	-87.98	0.00
P039 Number of litters of pigs	-29.39	0.00
P040 Number of hogs fed	-5.03	0.00
P051 Bushels of corn bought	0.19	-1.30
P054 Bushels of soybeans sold	0.00	2.70
P055 Tons of hay baled	7.57	-6.65
P056 Tons of hay sold	3.40	18.00
P058 Acres of cropland rented	-13.14	-20.00
P060 Acres of rotated pasture rented out	34.95	15.00
P061 Acres of rotated pasture acquired	-33.90	-15.00
P062 Acres of permanent pasture rented out	15.65	6.65
P071 Cwt. choice steer calf sold	3.88	28.75
P072 Cwt. choice yearling steer sold in fall	0.00	27.50
P076 Cwt. common yearling steer bought	1.21	-24.00
P077 Cwt. good yearling steer sold	0.00	25.50
P078 Cwt. choice heifer calf bought	2.96	-28.00
P084 Cwt. milk sold	0.00	4.50
P086 Cwt. feeder pigs bought October	2.52	-36.00
P087 Cwt. feeder pigs sold October	0.00	36.00
P088 Cwt. feeder pigs bought December	0.00	-36.00
P089 Cwt. feeder pigs bought February	1.80	-36.00
P090 Cwt. feeder pigs sold February	0.72	36.00

Table 12 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P091 Cwt. feeder pigs bought April	0.00	-36.00
P092 Cwt. feeder pigs sold April	0.00	36.00
P093 Cwt. feeder pigs bought June	0.60	-36.00
P094 Cwt. feeder pigs bought August	0.00	-36.00
P095 Cwt. feeder pigs sold August	1.46	36.00
P096 Cwt. market hogs sold winter	0.00	19.00
P097 Cwt. market hogs sold spring	0.00	19.00
P098 Cwt. market hogs sold summer	0.23	19.00
P099 Cwt. market hogs sold fall	0.00	19.00
P101 5 acre rotation of C-SB-C-O-M on land I	0.00	-124.00
P103 4 acre rotation of C-C-O-M on land I	5.66	-98.70
P104 5 acre rotation of C-C-O-M-M on land I	3.26	-102.70
P128 Dairy cow on grain and hay ration	0.00	-125.90
P129 Dairy cow on silage, grain and hay ration	0.00	-130.90
P151 Choice steer calves on grain and hay	9.51	-26.44
P152 Choice steer calves on silage, grain and hay ration	1.81	-27.94
P153 Choice yearling steers on grain and hay	13.57	-21.41
P155 Common yearling steers on grain and hay	9.42	-16.51
P156 Common yearling steers on silage, grain and hay ration	0.00	-19.51
P157 Choice heifers on grain and hay ration	19.95	-22.94
P168 Sow and two litters farrowed in December and June	0.00	-90.70
P169 Sow and two litters farrowed in February and August	0.00	-90.70
P180 Feeder pigs started in December	0.00	-7.175
P181 Feeder pigs started in February	0.00	-7.175
P182 Feeder pigs started in April	0.00	-7.175
P183 Feeder pigs started in June	0.00	-7.175
P184 Feeder pigs started in August	1.34	-7.175
P185 Feeder pigs started in October	0.04	-7.175

Table 12 (Continued)

Section 3

Restrictions that are limiting the plan	Marginal value product
R01 Hours winter operator labor available	0.00
R02 Hours spring operator labor available	1.60
R03 Hours summer operator labor available	1.60
R04 Hours fall operator labor available	1.60
R13 Winter cash expenses	0.07
R14 Spring cash expenses	0.07
R15 Summer cash expenses	0.07
R16 Fall cash expenses	0.07
R17 Winter livestock purchases	0.07
R19 Summer livestock purchases	0.04
R20 Fall livestock purchases	0.07
R21 Acres land quality I	36.47
R22 Acres land quality II	32.61
R29 Corn grain harvest transfer, bushel	1.20
R30 Corn silage transfer, ton	8.35
R31 Soybean transfer, bushel	2.70
R32 Standing meadow transfer, hay equiv. ton	17.84
R33 Hay transfer, ton	21.40
R34 Permanent pasture transfer, hay equiv. ton	17.84
R35 Feeding corn transfer, bushel	1.20
R38 Milk transfer, cwt.	4.50
R39 Choice steer calf feeder transfer, cwt.	32.64
R40 Choice yearling steer feeder transfer, cwt.	28.89
R41 Common yearling steer feeder transfer, cwt.	24.47

Table 12 (Continued)

Section 3

Restrictions that are limiting the plan	Marginal value product
R42 Choice heifer calf feeder transfer, cwt.	27.00
R43 Summer choice fed beef transfer, cwt.	27.50
R44 Fall choice fed beef transfer, cwt.	27.50
R45 Spring good fed beef transfer, cwt.	25.50
R46 Choice fed heifer transfer, cwt.	25.50
R47 Winter choice fed beef transfer, cwt.	27.50
R50 Feeder pig transfer, cwt. December	38.52
R51 Feeder pig transfer, cwt. February	36.72
R52 Feeder pig transfer, cwt. April	36.00
R53 Feeder pig transfer, cwt. June	35.40
R54 Feeder pig transfer, cwt. August	37.46
R55 Feeder pig transfer, cwt. October	36.00
R56 Market hog transfer, cwt. winter	19.00
R57 Market hog transfer, cwt. spring	19.00
R58 Market hog transfer, cwt. summer	19.23
R59 Market hog transfer, cwt. fall	19.00
R66 Dairy cow capacity, head	87.98
R67 Beef cow capacity, head	-28.26
R68 Fed beef capacity, head	24.08
R76 Hog farrowing capacity, litters	29.39
R77 Hog feeding capacity, head	5.03
R84 Breeding stock investment	0.06
C Net farm income	11,699.37

Situation D

The last model, Situation D, was structured so as to maximize hog production within the facility constraints while eliminating beef feeding. A beef cow activity was provided in the model but was not forced into the solution. The resource and enterprise constraints are specified in Table 13.

To make the data changes from Situation C to Situation D, no data within the matrix were altered. Instead, a new bounds section was substituted at the end of the data deck. Eighteen cards were substituted to specify both the new bounds and those that were unchanged from Situation C.

The results from Situation D are reported in Table 14. Total computation time was 1.15 minutes.

The total resource demands for the plan which results from Situation D are generally less than those required in Situation C. Labor requirements are slightly less while some winter operator labor is unused. Total capital requirements are reduced from $51,389.82 to $35,527.85. Almost half of the capital requirement in Situation D arises from breeding stock investment.

Corn production again dominated the cropping system, and about one-third of the crop was sold. Even though the total number of hogs fed equaled the number farrowed, the optimum plan specified selling the pigs farrowed in February and June as feeder pigs rather than finishing them for sale as slaughter hogs. Additional feeder pigs were purchased in December to feed during a period when unused operator labor was available.

The marginal value products of the facility and/or enterprise con-

Table 13. Resource and facility constraints for Situation D

All constraints are the same as those listed for Situation C except for the following:

	Level	Type
P037 Number of beef cows	50.0	Upper bound
P038 Number of cattle fed	0.0	Upper bound
P039 Number of litters of pigs	60.0	Fixed bound
P040 Number of hogs fed	420.0	Fixed bound

Table 14. Optimum solution to farm Situation D

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P001 Hours winter operator labor used	809.35	0.00
P002 Hours spring operator labor used	650.00	0.00
P003 Hours summer operator labor used	690.00	0.00
P004 Hours fall operator labor used	520.00	0.00
P006 Hours spring labor hired	244.29	-1.50
P007 Hours summer labor hired	3.15	-1.50
P008 Hours fall labor hired	8.66	-1.50
P009 Total cash expense and livestock investment	35,527.85	0.00
P010 Winter cash expenditures	5,225.49	-0.07
P011 Spring cash expenditures	4,798.91	-0.07
P012 Summer cash expenditures	2,538.08	-0.07
P013 Fall cash expenditures	3,761.97	-0.07
P014 Breeding stock investment	17,043.40	-0.06
P015 Winter livestock purchases	2,160.00	-0.07
P019 Winter cash receipts	2,814.61	0.00
P020 Spring cash receipts	2,814.61	0.00
P021 Summer cash receipts	53.25	0.00
P023 Winter livestock receipts	12,544.95	0.00
P024 Spring livestock receipts	3,798.03	0.00
P025 Summer livestock receipts	5,792.88	0.00
P026 Fall livestock receipts	5,507.28	0.00
P030 Acres of corn	130.00	0.00
P032 Acres of oats	50.00	0.00
P033 Acres of meadow	70.00	0.00
P037 Number of beef cows	50.00	0.00
P039 Number of litters of pigs	60.00	0.00
P040 Number of hogs fed	420.00	0.00

Table 14 (Continued)

Section 1

Activities in the optimum plan	Level of activity in plan	Net price from original model
P050 Bushels of corn sold	4,691.01	1.20
P052 Bushels of corn fed	6,808.91	0.00
P055 Tons of hay baled	93.00	-6.65
P056 Tons of hay sold	2.96	18.00
P063 Tons of meadow used as pasture	96.03	0.00
P071 Cwt. choice steer calf sold	100.96	28.75
P079 Cwt. choice heifer calf sold	50.00	27.00
P080 Cwt. choice fed heifer sold	70.02	25.50
P088 Cwt. feeder pigs bought December	60.00	-36.00
P092 Cwt. feeder pigs sold April	30.00	36.00
P095 Cwt. feeder pigs sold August	30.00	36.00
P096 Cwt. market hogs sold winter	660.00	19.00
P097 Cwt. market hogs sold spring	143.00	19.00
P098 Cwt. market hogs sold summer	154.00	19.00
P099 Cwt. market hogs sold fall	66.00	19.00
P102 5 acre rotation of C-C-C-O-M on land I	40.00	-140.05
P105 5 acre rotation of C-O-M-M-M on land II	10.00	-68.35
P140 Beef cow on pasture	50.00	-21.00
P168 Sow and two litters farrowed in December and June	10.00	-90.70
P169 Sow and two litters farrowed in February and August	20.00	-90.70
P180 Feeder pigs started in December	150.00	-7.175
P181 Feeder pigs started in February	65.00	-7.175
P182 Feeder pigs started in April	55.00	-7.175
P185 Feeder pigs started in October	150.00	-7.175
P200 Real estate taxes	1,250.00	-1.00
P201 Machinery depreciation	1,900.00	-1.00
P202 Building depreciation	850.00	-1.00

Table 14 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P005 Hours winter labor hired	1.60	-1.50
P016 Spring livestock purchases	0.07	-0.07
P017 Summer livestock purchases	0.07	-0.07
P018 Fall livestock purchases	0.07	-0.07
P022 Fall cash receipts	0.00	0.00
P031 Acres of soybeans	0.02	0.00
P036 Number of dairy cows	-125.12	0.00
P038 Number of cattle fed	-59.90	0.00
P051 Bushels of corn bought	0.19	-1.30
P053 Tons of corn silage harvested	0.00	-0.95
P054 Bushels of soybeans sold	0.00	2.70
P057 Tons of hay bought	3.40	-20.00
P058 Acres of cropland rented	0.64	-20.00
P060 Acres of rotated pasture rented out	4.24	15.00
P061 Acres of rotated pasture acquired	-3.19	-15.00
P062 Acres of permanent pasture rented out	1.94	6.65
P070 Cwt. choice steer calf bought	1.75	-30.50
P072 Cwt. choice yearling steer sold in fall	1.78	27.50
P073 Cwt. choice yearling steer bought	3.59	-27.00
P074 Cwt. choice yearling steer sold in summer	0.00	27.50
P075 Cwt. choice yearling steer long fed sold in winter	0.00	27.50
P076 Cwt. common yearling steer bought	4.88	-24.00
P077 Cwt. good yearling steer sold	0.00	25.50

Table 14 (Continued)

Section 2

Activities not in the optimum plan	Income penalty per unit of activity if forced into plan	Net price from original model
P078 Cwt. choice heifer calf bought	1.00	-28.00
P084 Cwt. milk sold	0.00	4.50
P086 Cwt. feeder pigs bought October	0.00	-36.00
P087 Cwt. feeder pigs sold October	0.00	36.00
P089 Cwt. feeder pigs bought February	0.51	-36.00
P090 Cwt. feeder pigs sold February	2.01	36.00
P091 Cwt. feeder pigs bought April	0.00	-36.00
P093 Cwt. feeder pigs bought June	0.60	-36.00
P094 Cwt. feeder pigs bought August	0.00	-36.00
P101 5 acre rotation of C-SB-C-O-M on land I	0.00	-124.00
P103 4 acre rotation of C-C-O-M on land I	12.24	-98.70
P104 5 acre rotation of C-C-O-M-M on land I	33.97	-102.70
P128 Dairy cow on grain and hay ration	0.00	-125.90
P129 Dairy cow on silage, grain and hay ration	0.00	-130.90
P150 Choice steer calves long fed on pasture	0.00	-22.10
P151 Choice steer calves on grain and hay ration	6.44	-26.44
P152 Choice steer calves on silage, grain and hay ration	0.00	-27.94
P153 Choice yearling steers on grain and hay ration	11.19	-21.41
P154 Choice yearling steers on silage, grain and hay ration	0.00	-23.66
P155 Common yearling steers on grain and hay ration	7.72	-16.51
P156 Common yearling steers on silage, grain and hay ration	0.00	-19.51
P157 Choice heifers on grain and hay ration	53.05	-22.94
P183 Feeder pigs started in June	0.00	-7.175
P184 Feeder pigs started in August	0.24	-7.175

Table 14 (Continued)

Section 3

Restrictions that are limiting the plan	Marginal value product
R02 Hours spring operator labor available	1.60
R03 Hours summer operator labor available	1.60
R04 Hours fall operator labor available	1.60
R13 Winter cash expenses	0.07
R14 Spring cash expenses	0.07
R15 Summer cash expenses	0.07
R16 Fall cash expenses	0.07
R17 Winter livestock purchases	0.07
R21 Acres land quality I	29.89
R22 Acres land quality II	14.18
R29 Corn grain harvest transfer, bushel	1.20
R30 Corn silage transfer, ton	8.35
R31 Soybean transfer, bushel	2.70
R32 Standing meadow transfer, hay equiv. ton	6.87
R33 Hay transfer, ton	18.00
R34 Permanent pasture, transfer, hay equiv. ton	6.87
R35 Feeding corn transfer, bushel	1.20
R38 Milk transfer, cwt.	4.50
R39 Choice steer calf feeder transfer, cwt.	28.75
R40 Choice yearling steer feeder transfer, cwt.	23.41
R41 Common yearling steer feeder transfer, cwt.	19.12
R42 Choice heifer calf feeder transfer, cwt.	27.00
R43 Summer choice fed beef transfer, cwt.	27.50

Table 14 (Continued)

Section 3

Restrictions that are limiting the plan	Marginal value product
R44 Fall choice fed beef transfer, cwt.	29.28
R45 Spring good fed beef transfer, cwt.	25.50
R46 Choice fed heifer transfer, cwt.	25.50
R47 Winter choice fed beef transfer, cwt.	27.50
R50 Feeder pig transfer, cwt. December	38.52
R51 Feeder pig transfer, cwt. February	38.01
R52 Feeder pig transfer, cwt. April	36.00
R53 Feeder pig transfer, cwt. June	35.40
R54 Feeder pig transfer, cwt. August	36.00
R55 Feeder pig transfer, cwt. October	36.00
R56 Market hog transfer, cwt. winter	19.00
R57 Market hog transfer, cwt. spring	19.00
R58 Market hog transfer, cwt. summer	19.00
R59 Market hog transfer, cwt. fall	19.00
R66 Dairy cow capacity, head	125.12
R67 Beef cow capacity, head	11.69
R68 Fed beef capacity, head	59.90
R76 Hogs farrowing capacity, litters	31.24
R77 Hog feeding capacity, head	4.52
R84 Breeding stock investment	0.06
C Net farm income	10,774.30

straints indicate that all livestock enterprises are still profitable. Dairy cows have an especially high marginal value of $125.12 per head. The beef feeding activity also shows a marginal income contribution of $59.90 per head. It should be noted that the marginal value product of additional farrowing capacity is greater in Situation D than in Situation C, where no hogs were produced.

The increases in marginal income contributions are explained by the fact that in Situation C a considerable amount of rotated pasture was required to meet the needs of the beef animals. Producing additional pasture consuming livestock, including litters of pigs, would have forced some corn acres into rotated pasture. Additional pasture consuming livestock would be competing with corn production in Situation C but not in Situation D, where little pasture was needed.

Application of the Model

The four situations programmed illustrate several unique applications of a linear programming model. In terms of solving individual farm planning problems, the use of the partially optimized or even a completely budgeted problem can serve at least two purposes.

First, the present organization of enterprises for the farm under study can be approximated with the model to determine a resource use and income base with which to compare optimized solutions. The bounding of particular individual activities, as shown in all four situations presented, would accommodate such an approximation of a business organization.

To optimize the same set of resources would only require replacing the data cards that restrict the various activities. None of the production coefficients within the data deck need be disturbed.

The second application of the partial optimization model would be in comparing alternative business organizations to either the optimum organization or the existing organization of the farm business. If the optimum organization indicates an unsatisfactory return to capital or some other resource, the farm planner may be able to specify some alternative organization in which net income is reduced only slightly while the use of resources with a low marginal productivity are cut back substantially.

The relative ease of changing resource or activity restraints makes the model useful for a variety of farm planning problems. In addition to its potential use as a farm planning tool for individual farm situations, the model has potential in the classroom or extension situation in which farm organization principles are taught. Students can test various plans evolved by methods such as budgeting or even informed guesses against optimum resource use.

The description of total capital requirements and cash flow could also assist the farm operator in determining what his credit needs would be in each of the production seasons. Such a description could assist in acquiring additional credit in short period of capital limitations if it could be shown that the productivity of the additional capital warranted the extension of additional credit.

The use of the marketing activities defined in terms of commonly used units, especially with livestock, can assist the planner in better defining the prices that must be paid or received to equate the profitability of alternative livestock activities. These marketing activities eliminate much of the additional hand budgeting formerly required to interpret the shadow prices from a solution.

SHORTCOMINGS OF THE MODEL

Although the programming model illustrated in the previous chapter generally meets the original goals specified, there are several shortcomings that ought to be considered.

First, the capital used in each production period was charged a full year's interest, even though the capital may have been invested during only two or three periods. The original intent was to charge only the amount of interest due for the actual time the capital was required for each activity. However, to do so would have required capital profiles for each activity. Such an accounting system would have recorded the accrued amount of capital required in each activity for each season. Cash flow accounting would have been more difficult with the capital profile system, however. It was decided that an accounting of cash flow was more useful than the insights into the farm business provided by a more elaborate profile of capital needs. Because of the manner in which capital coefficients and capital supplying activities have been structured, however, the actual interest charge would be less than the cost of capital implied in the present model.

The second problem also involves the cash flow accounting system. Although the marketing activities for all commodities are defined in conventional marketing units and the net prices are easily changed, the accounting for the cash expenses and receipts for such activities is defined within the programming matrix. Therefore, when the net prices are changed, the cash expenses and receipts remain the same. The activity mix is optimized with altered net prices, but the expenses and receipts record the original cost or sale price. The seasonal cash accounting activities become only approximations as the price expectations of the marketing activities deviate from those prices built into the cash accounting section of the matrix.

At this time, the only method visualized to deal with the cash accounting problem would be to add a computer program that would multiply the units of each marketing activity on the optimum solution times the net price of that activity. The product totals for each activity would then be added to the product totals of other marketing activities that occurred in the same season. These totals, in turn, would be the seasonal marketing receipts and expenses. Receipts and expenses computed in this manner would reflect variations in cash flow when variable price programming was used.

An additional problem encountered with the model was in the printed output. The income penalties for some activities not in the optimum plan were sometimes difficult to trace. Two examples are soybean and beef production.

Soybeans did not enter the solution in any of the four situations programmed. However, no income penalty for growing soybeans was printed for the crop rotation activity that included soybeans. Instead the income penalty was associated with marketing the crop. In this instance, the income penalty was easier to interpret than if it had been printed with the crop growing activity. Interpretation of the shadow prices for beef production was not as straightforward.

As an example, the printed output for Situation A showed that the maximum amount of beef cattle were fed. Section 2 listed the income penalties for the beef feeding activities that were not in the optimum plan. However, the only marginal value product associated with beef feeding given in Section 3 was for the total feeding capacity. No value was given to indicate which feeding activity would be the most profitable. The interpretation must be made that since a single feeding activity entered at the maximum level, that same activity would be the most profitable one to expand.

The conclusion is that, even though most of the desired information is given in the report, some additional interpretation may be necessary by someone who is familiar with linear programming techniques and interpretation of results.

Therefore, the printed output from each farm planning problem may not be satisfactory to send directly to a typical farm operator. It may always be necessary to include an additional written interpretation or to require a return visit by the planner to the farm being programmed.

CONCLUSIONS AND SUGGESTED MODIFICATIONS OF THE MODEL

Through the development of the demonstration model and presentation of several problem situations, it has been shown that a linear programming model can be constructed to 1) leave the basic input-output data undisturbed from one farm situation to another, 2) formulate activity prices in such a manner that price expectations can be easily altered, 3) provide a readily interpretable descriptive output report for each solution, and 4) allow for partial optimization or complete budgeting of a given farm situation. To make this model more applicable to a variety of farm situations, several additional steps need to be taken.

The model constructed for this project needs additional production alternatives. The present model allows for only five cropping activities, eight beef raising and/or feeding activities, two dairy activities, and eight hog raising and/or feeding activities. To more accurately define the alternatives for a variety of farm businesses, a greater number of crop and livestock activities are needed. Most additional production activities would not require additional marketing activities since the present marketing activities define a wide variety of alternatives.

Production activities are needed to define different levels of management and production methods. Three levels of management should be defined within each production method. The farm operator and/or the farm planner could identify the historic or potential management level for each activity. Allowing for differences in management ability among enterprises would more closely approximate a farm operator's ability. Few farmers have the same management ability for all crop and livestock enterprises.

In addition to increasing the number of production activities based on management levels and production methods, activities describing economies or costs of volume could be added, especially for partial optimization problems. If minimum levels of production are specified, activities that define increasing or decreasing costs of production would assist in more accurately describing input-output relationships.

After the model has been enlarged to include a satisfactory number of production methods with their associated management levels and increasing or decreasing costs, the next step should be to store all of the input-output data within a computer system in such a manner that any or all activities could be called out of storage for use in a farm planning problem. Storing the data in computer accessory would alleviate the many problems and potential errors associated with handling a large number of data cards. Solving a farm planning problem with computer-stored activities would then require four steps.

First, the resource restrictions would need to be defined for each farm by listing the B-column row number for each non-zero resource constraint and its associated value. Such resources as seasonal operator labor, acres of each class of land and tons of permanent pasture would be defined in this manner.

Second, the activities to be used for a farm planning problem would need to be called out of storage by punching the number of each activity desired on a data card. All activities not listed would not be considered as alternatives in solving the problem. Reducing the number of possible activities in this manner rather than bounding all unnecessary activities at zero level would both reduce computation time and provide an output report that considered only the relevant activities.

Third, the price expectations would need to be defined if they were different from those stored with the input-output data. A set of price expectations would be provided within the stored data, but if the farm planner and/or operator desired some changes, those price expectations would need to be specified by listing the activity number, the C-row, and the changed price.

Fourth, all facility constraints and minimum or maximum levels of production would need to be specified by bounding the necessary accounting activities. Upper bounds would need to be specified to define the physical capacity of livestock or crop facilities. Lower or fixed bounds would need to be specified for minimum or fixed levels of production for partial optimization problems. In some instances it would be desirable to specify minimum or fixed levels of production of a specific production activity rather than of the accounting activity. All bounding would be done as it is with the present model. The program should be designed so that upon completion of each farm planning problem, all resources, selected activities, specified prices, and bounds would be erased before a new problem was encountered. There would be no chance of carrying restrictions or price expectations from one problem to another. Instead, each problem would be handled independently of any other preceding or following it.

After a satisfactory method has been developed to store the input-output data and select activities from it, the next step would be to design information sheets for the farm operator or planner to specify the necessary information to solve a planning problem. The sheets should be designed

Table 15. Example of initial information sheets

First page

Resources Available

Hours of operator labor available from December 1 to April 15	920.0
Hours of operator labor available from April 15 to June 30	650.0
Hours of operator labor available from July 1 to September 30	690.0
Hours of operator labor available from October 1 to November 30	520.0
Acres of Class I land in farm	200.0
Acres of Class II land in farm	50.0
Etc.	

Activities to be considered from catalog

P001, P002, P003, P004, P005, P006, P007,
P008, P012, P013, P014, P015, P016, P017,
Etc.

Price Expectations (net at farm prices)

Sell corn, bushel	1.15
Buy corn, bushel	1.25
Sell soybeans, bushel	2.60
Winter sale price of 220# market hogs, cwt.	20.50
Spring sale price of 220# market hogs, cwt.	20.00
Purchase price 450# choice steer calf, cwt.	31.25
Sale price 1050-1125# choice fed steer, cwt.	27.75
Etc.	

Production Limitations

Maximum acres of corn	130.0	Minimum acres of corn	80.0
Maximum acres of soybeans	50.0	Minimum acres of soybeans	20.0

Table 15 (Continued)

Second page

RHS

B	R01	920.0
B	R02	650.0
B	R03	690.0
B	R04	520.0
B	R21	200.0
B	R22	50.0

COLUMNS

P001, P002, P003, P004, P005, P006, P007,
P008, P012, P013, P014, P015, P016, P017

P050	C	1.15
P051	C	-1.25
P054	C	2.60
P096	C	20.50
P097	C	20.00
P070	C	-31.25
P072	C	27.75

BOUNDS

UP	P030	130.0	LO	P030	80.0
UP	P031	50.0	LO	P030	20.0

in such a manner that the operator or planner would answer specific printed questions relating to resource constraints, activity selection, price expectations, and minimum, fixed, or maximum levels of production. The answers printed in the blanks following the questions could be copied on a second page with carbon paper. The second sheet, listing additional necessary column and row identification numbers, could be detached and used as a guide for punching the data cards. Such a system would help eliminate much of the intermediate work usually needed to translate information gathered on the farm to data sheets before card punching is done. An example of the type of information sheet described above is shown in Table 15.

Before such data sheets could be used, however, a master catalog would need to be printed identifying all stored activities by number and name and defining all production coefficients. From this catalog, the farm operator and/or planner could choose those activities desired as possible alternatives. In addition, the stored set of price expectations would be listed so the operator could decide whether he wanted to define a different set or select the stored set. The master catalog would be printed in much the same format as the present "Suggested Costs and Returns for Use in Farm Budgeting" but, of course, would contain much more detailed information (24).

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APPENDIX A

Description of the Monona-Ida-Hamburg Soil Association Area*

The Monona-Ida-Hamburg soil association area covers about 2,900 square miles or 5 percent of the state. It extends from Plymouth County on the north to Fremont County on the south. It is most extensive in Woodbury, Monona, Harrison and West Pottawattamie counties but also occurs in parts of seven additional counties.

The topography of the area is characterized by narrow, gently-sloping ridges and steep side slopes which gradually change to well-defined alluvial valleys. Deeply entrenched streams and gullies are common in the alluvial valleys. In the Missouri River bluff area, very steep upland side slopes have eroded to form small natural benches called catsteps.

Nearly all upland soils of the area formed from thick deposits of loess which covered the rolling glacial till plain. Till-derived soils such as Shelby and Adair occur but are monor. A few areas of Malvern, a soil developed from Loveland loess, also occur. Silty materials eroded from the uplands formed the parent materials of the stream valleys.

The native vegetation was primarily prairie, although some small trees and shrubs grew on some steep east and north-facing slopes.

Monona, Ida and Hamburg are the major upland soils. Napier and McPaul are two of the major soils of the stream valleys.

Monona are well-drained soils that occur on the gently sloping narrow

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*Source: (20, pp. 55-58).

ridges and strongly sloping side slopes. Slopes of 5 to 14 percent are most common, but these soils do occur on slopes ranging from 1 to 30 percent. The surface layer is a very dark brown silt loam 8 to 14 inches thick. The surface layer is frequently partially or completely removed by erosion. The subsoil is a dark brown to brown silt loam. The substratum is silt loam loess which may be calcareous at depths of 30 to 100 inches.

Ida soils occur on narrow divides and steep side flanks on slopes of 6 to 30 percent. Slopes of 10 to 20 percent are common. They are calcareous throughout the profile and do not have B horizons. In uneroded areas, the surface layer is a very dark grayish-brown calcareous silt loam 6 to 10 inches thick. The substratum is yellowish-brown calcareous silt loam loess. In most cultivated areas, the surface layer has eroded away and the substratum is exposed.

Dow soils have surface layers which are similar to the Ida soils in color and texture but have calcareous olive gray silt loam substrata. They are monor soils in the area.

Hamburg soils occur on steep (30 to 60 percent) catstep slopes adjacent to the Missouri River bottomlands and along drainageways which outlet into the bottomland. They formed from thick, coarse loess with prairie the principal vegetation. They have a very thin calcareous, dark brown silt to silt loam surface layer over a substratum of calcareous, pale brown coarse silt loess.

Castana soils are forming from calcareous colluvial materials which washed or slumped down from the steep Hamburg and Ida soils. They occur on High upland footslopes primarily of 10 to 30 percent. They have very dark brown to very dark grayish-brown surface layers 20 to 24 inches thick that are calcareous in the lower part. The substratum is a calcareous yellowish-brown silt loam.

Napier soils occur along upland drainageways and narrow streams and on footslopes. These well-drained soils occur on slopes of 1 to 10 percent. Napier soils have a very dark brown silt loam surface layer, 20 to 30 inches thick, and moderately permeable, dark brown silt loam subsoil and substratum. In some areas recent sediments have formed a layer up to 10 inches thick on the surface.

McPaul soils are forming from alluvial materials in stream valleys. They consist of 24 to 36 inches or more of light colored sediments over buried dark colored silty clay loam soils.

A moderately high percentage of this association is used for cultivated crops. The steep slopes, including the catsteps bordering the Missouri River valley and some of its main tributaries, are in permanent pasture. Some areas of shrubs and trees occur. Yields are low from both pasture and timber on these steep slopes.

The valleys, less steep side slopes and the ridges are usually cultivated. Some of the streams in the area have been straightened to permit cultivation of much of the valley land. Gullying is a serious problem throughout most of the association, as gullies enlarge rapidly and attain huge proportions. Nitrogen and phosphorous are commonly needed. Ida soils are especially deficient in available phosphorous. Lime is not generally needed since most of the soils are neutral or slightly acid. Gently sloping to sloping Monona soils are often acid and may need lime. The sloping soils of the area are very erosive and require terracing, contour listing and other soil conservation practices for adequate erosion control.

Table 16. Land use, fertility levels, and corn production potentials of major soil types and phases in Monona-Ida-Hamburg soil association area

Soil type	Phase		Lime needs	Average soil test[b]			Maximum corn use with conservation practices[c]	Corn yield potential	Land capability class and
Number and name	Slope	Erosion	T/acre[a]	N	P	K		bu/acre	subclass
10 Monona silt loam	2-5	1	0-3	L	VL to L	M to H	Often	85	II e
10 Monona silt loam	5-9	2	0-3	VL to L	VL to L	M to H	Occasionally	80	III e
10 Monona silt loam	9-14	3	0	VL	VL to L	M to H	Seldom	75	III e
1 Ida silt loam	5-9	2	0 (ex)	L	VL	M to H	Occasionally	65	III e
1 Ida silt loam	9-14	3	0 (ex)	VL to L	VL	M to H	Seldom	60	III e
1 Ida silt loam	14-18	3	0 (ex)	VL	VL	M to H	Seldom	55	IV e
2 Hamburg silt loam	30+	3	0 (ex)	VL	VL	H	Never	-	VII e
3 Castana silt loam	14-18	1	0 (ex)	L	VL to L	M to H	Seldom	60	IV e
12 Napier silt loam	2-5	0	0-2	L to M	VL to L	M to H	Often	90	II e
70 McPaul silt loam	0-2	0	0	VL to L	L to M	H	Often	86	I

[a]Estimated range for soils not limed in past 5 years. Lime needs indicated are near optimum rates recommended on ISU soil test reports.

[b]Estimated average soil test values based in part on summary of over 350,000 samples tested at the ISU Soil Testing Laboratory.

[c]Often=3 or more years out of 5; Occasionally=1 to 3 years out of 5; Seldom=not more than 1 year in 6; Never=permanent vegetation.

APPENDIX B

Allocation of Production Coefficients for Crop and Livestock Activities

Crop Activities	Power and machine cost	Seed	Fertilizer and lime	Miscellaneous
Corn 1 acre grown and harvested				
Winter	$ 2.00	$0.00	$ 0.00	$0.00
Spring	5.80	3.00	3.00	3.00
Summer	1.45	0.00	0.00	0.00
Fall	7.10	0.00	9.00[a]	1.00
Total	$16.35	$3.00	$12.00	$4.00
Soybeans 1 acre grown and harvested				
Winter	$ 2.00	$0.00	$ 0.00	$0.00
Spring	5.10	3.00	6.00	3.00
Summer	0.00	0.00	0.00	0.00
Fall	6.20	0.00	0.00	0.00
Total	$13.30	$3.00	$ 6.00	$3.00
Oats-Meadow 2 acres grown, oats harvested				
Winter	$ 1.50	$0.00	$ 0.00	$0.00
Spring	4.50	6.00	6.00[b]	1.00
Summer	4.00[c]	0.00	0.00	1.00
Fall	1.00	0.00	0.00	0.00
Total	$11.00	$6.00	$ 6.00	$2.00

[a]$3.00 additional fertilizer is added for each additional year land remains in corn production.

[b]$3.00 fertilizer is applied for each year land remains in meadow.

[c]$1.00 power and machine cost is added for pasture maintenance for each additional year in meadow.

Figure 1. Seasonal allocation of capital requirements for crop activities

	Power and machine cost	Seed	Fertilizer and lime	Miscellaneous	Labor
Corn silage	1 acre grown and harvested[a]				
Winter	$ 2.00	$0.00	$ 0.00	$0.00	0.0
Spring	5.80	3.00	3.00	3.00	2.6
Summer	1.45	0.00	0.00	1.00	7.3
Fall	20.60[b]	0.00	15.00	0.00	0.5
Total	$29.85	$3.00	$18.00	$4.00	10.4
Hay baling	1 ton baled				
Winter	$ 0.00	$0.00	$ 0.00	$0.00	0.0
Spring	2.50[c]	0.00	0.00	0.00	1.2
Summer	4.15	0.00	0.00	0.00	1.3
Fall	0.00	0.00	0.00	0.00	0.0
Total	$ 6.65	$0.00	$ 0.00	$0.00	2.5

[a]The activity in the matrix is based on the requirements to harvest one ton of silage. The coefficients used specify the difference in capital and labor requirements between harvesting for grain and harvesting for silage, using the conversion figure of 5.6 bushels of corn per ton of silage.

[b]Based on a custom hire charge of $15.00 per acre, plus machinery costs on owned equipment.

[c]Based on a custom hire charge of 11¢ per bale, plus machinery costs on owned equipment.

Figure 1 (Continued)

Livestock Activities	Supplements and minerals	Breeding charge	Veterinary and medical expense	Power and machine cost	Insurance and taxes	Miscellaneous
Beef cow	1 cow and calf raised to weaning, with accompanying replacement stock[a]					
Winter	$ 2.00	$1.00	$ 1.05	$ 2.00	$2.10	$0.60
Spring	1.37	0.80	1.05	0.75	0.00	0.45
Summer	1.38	0.55	1.05	0.50	2.10	0.00
Fall	0.75	0.80	0.00	0.70	0.00	0.00
Total	$ 5.50	$3.15	$ 3.15	$ 3.95	$4.20	$1.05
Dairy cow	Grain and hay ration, 1 cow with accompanying replacement stock[b]					
Winter	$18.45	$3.40	$ 6.70	$19.90	$3.20	$2.35
Spring	5.40	1.80	3.70	7.00	1.80	1.30
Summer	4.60	2.30	4.45	11.95	2.10	1.60
Fall	8.05	1.50	3.00	9.00	1.40	1.05
Total	$36.50	$9.00	$17.85	$47.85	$8.50	$6.30
Dairy cow	Silage, grain and hay ration, 1 cow with accompanying replacement stock[b]					
Winter	$21.45	$3.40	$ 6.70	$19.90	$3.20	$2.35
Spring	5.90	1.80	3.70	7.00	1.80	1.30
Summer	4.60	2.30	4.45	11.95	2.10	1.60
Fall	9.55	1.50	3.00	9.00	1.40	1.05
Total	$41.50	$9.00	$17.85	$47.85	$8.50	$6.30

[a]Breeding stock investment for beef cow = cow = $225.00, 1/5 yearling hfr. = $25.00, 1/7 bred hfr. = $28.57, and 1/25 bull = $16.00. Total = $294.57.

[b]Breeding stock investment for dairy cow = cow = $350.00, 1/3 yearling hfr. = $60.00, 1/5 bred hfr. = $55.00, and 1/2 calf = $25.00. Total = $490.00.

Figure 2. Seasonal allocation of capital requirements for dairy and beef cow activities

Livestock Activities	Supplements and minerals	Veterinary and medical expense	Power and machine cost	Insurance and taxes	Miscellaneous
Choice steer calf pastured and long term fed					
Winter	$ 3.40	$0.00	$1.20	$1.05	$0.00
Spring	1.90	1.00	0.75	0.00	0.50
Summer	1.00	0.00	1.00	0.00	0.00
Fall	4.00	1.00	2.00	0.00	0.55
Total	$10.30	$2.00	$4.95	$1.05	$1.05
Choice steer calf, grain and hay or silage, grain and hay ration[a]					
Winter	$ 5.10	$1.10	$2.20	$1.30	$1.05
Spring	2.50	0.70	1.00	0.00	0.00
Summer	2.90	0.50	1.00	1.30	0.00
Fall	1.50	0.80	0.75	0.00	0.00
Total	$12.00	$3.10	$4.95	$2.60	$1.05
Choice yearling steer, grain and hay or silage, grain and hay ration[b]					
Winter	$ 5.50	$0.70	$2.60	$1.60	$0.50
Spring	2.00	0.40	1.35	0.00	0.00
Summer	0.00	0.00	0.00	0.00	0.00
Fall	1.50	1.00	1.00	1.00	0.55
Total	$ 9.00	$2.10	$4.95	$2.60	$1.05

[a]For silage, grain and hay ration, add $0.75 to summer and fall supplement of grain and hay ration. No other change.

[b]Silage ration coefficients same as grain ration coefficients, except for additional $0.75 in winter and fall, $0.50 in spring, and $0.25 in summer for supplement and minerals.

Figure 3. Seasonal allocation of capital requirements for beef feeding activities

Livestock Activities	Supplements and minerals	Veterinary and medical expense	Power and machine costs	Insurance and taxes	Miscellaneous
Common yearling steer, grain and hay or silage, grain and hay ration[a]					
Winter	$3.50	$1.05	$2.50	$1.30	$0.00
Spring	0.00	0.00	0.00	0.00	0.00
Summer	0.00	0.00	0.00	0.00	0.00
Fall	1.75	1.05	1.45	1.30	1.05
Total	$5.25	$2.10	$3.95	$2.60	$1.05
Heifer calf, grain and hay ration					
Winter	$4.50	$1.50	$2.20	$1.30	$1.05
Spring	1.50	0.50	1.50	1.30	0.00
Summer	1.00	0.00	0.50	0.00	0.00
Fall	1.50	1.50	0.75	0.00	0.00
Total	$8.50	$3.50	$4.95	$2.60	$1.05

[a]Silage ration coefficients same as grain ration coefficients except that $1.00 additional fall supplements and $2.00 additional winter supplements were used.

Figure 3 (Continued)

Livestock Activities	Supplements and minerals	Breeding charge	Veterinary and medical expense	Power and machine cost	Insurance and taxes	Miscellaneous
Sow and two litters farrowed in December and June[a]. Pigs carried to 40 lbs.						
Winter	$14.45	$0.00	$ 4.40	$ 3.67	$0.00	$0.85
Spring	21.30	1.60	3.25	6.35	1.05	0.00
Summer	7.50	0.00	2.00	2.00	0.00	0.85
Fall	14.35	1.55	0.85	4.68	0.00	0.00
Total	$57.60	$3.15	$10.50	$16.70	$1.05	$1.70
Sow and two litters farrowed in February and August[a]. Pigs carried to 40 lbs.						
Winter	$22.20	$0.00	$ 4.85	$ 6.35	$1.05	$0.85
Spring	10.35	1.60	0.60	3.20	0.00	0.00
Summer	18.45	0.00	4.65	5.15	0.00	0.85
Fall	6.60	1.55	0.40	2.00	0.00	0.00
Total	$57.60	$3.15	$10.50	$16.70	$1.05	$1.70
Feeder pig started in October at 40 lbs. and fed to market weight[b]						
Winter	$ 2.00	-	$ 0.375	$ 0.745	$0.105	$0.10
Spring	0.00	-	0.00	0.00	0.00	0.00
Summer	0.00	-	0.00	0.00	0.00	0.00
Fall	2.50	-	0.675	0.575	0.10	0.10
Total	$ 4.50	-	$ 1.05	$ 1.32	$0.205	$0.20

[a]Breeding stock investment = sow = $70.00, 1/30 boar = $7.00. Total = $77.00.

[b]Capital coefficients for feeder pig activities in other time periods were allocated from total capital requirement of $7.175 per pig.

Figure 4. Seasonal allocation of capital requirements for hog activities

APPENDIX C

Name and Numerical Code of All Activities and Restraints in the Model

Activities for Demonstration Model

P001 HOURS WINTER OPERATOR LABOR USED

P002 HOURS SPRING OPERATOR LABOR USED

P003 HOURS SUMMER OPERATOR LABOR USED

P004 HOURS FALL OPERATOR LABOR USED

P005 HOURS WINTER LABOR HIRED

P006 HOURS SPRING LABOR HIRED

P007 HOURS SUMMER LABOR HIRED

P008 HOURS FALL LABOR HIRED

P009 TOTAL CASH EXPENSE AND LIVESTOCK INVESTMENT

P010 WINTER CASH EXPENDITURES

P011 SPRING CASH EXPENDITURES

P012 SUMMER CASH EXPENDITURES

P013 FALL CASH EXPENDITURES

P014 BREEDING STOCK INVESTMENT

P015 WINTER LIVESTOCK PURCHASES

P016 SPRING LIVESTOCK PURCHASES

P017 SUMMER LIVESTOCK PURCHASES

P018 FALL LIVESTOCK PURCHASES

P019 WINTER CASH RECEIPTS

P020 SPRING CASH RECEIPTS

P021 SUMMER CASH RECEIPTS

P022 FALL CASH RECEIPTS

P023 WINTER LIVESTOCK RECEIPTS

P024 SPRING LIVESTOCK RECEIPTS

PO25 SUMMER LIVESTOCK RECEIPTS

PO26 FALL LIVESTOCK RECEIPTS

PO30 ACRES OF CORN

PO31 ACRES OF SOYBEANS

PO32 ACRES OF OATS

PO33 ACRES OF MEADOW

PO36 NUMBER OF DAIRY COWS

PO37 NUMBER OF BEEF COWS

PO38 NUMBER OF CATTLE FED

PO39 NUMBER OF LITTERS OF PIGS

PO40 NUMBER OF HOGS FED

PO50 BUSHELS OF CORN SOLD

PO51 BUSHELS OF CORN BOUGHT

PO52 BUSHELS OF CORN FED

PO53 TONS OF CORN SILAGE HARVESTED

PO54 BUSHELS OF SOYBEANS SOLD

PO55 TONS OF HAY BALED

PO56 TONS OF HAY SOLD

PO57 TONS OF HAY BOUGHT

PO58 ACRES OF CROPLAND RENTED

PO60 ACRES OF ROTATED PASTURE RENTED OUT

PO61 ACRES OF ROTATED PASTURE ACQUIRED

PO62 ACRES OF PERMANENT PASTURE RENTED OUT

PO63 TONS OF MEADOW USED AS PASTURE

PO70 CWT. CHOICE STEER CALF BOUGHT

PO71 CWT. CHOICE STEER CALF SOLD

P072 CWT. CHOICE YEARLING STEER SOLD IN FALL

P073 CWT. CHOICE YEARLING STEER BOUGHT

P074 CWT. CHOICE YEARLING STEER SOLD IN SUMMER

P075 CWT. CHOICE YEARLING STEER LONG FED SOLD IN WINTER

P076 CWT. COMMON YEARLING STEER BOUGHT

P077 CWT. GOOD YEARLING STEER SOLD

P078 CWT. CHOICE HEIFER CALF BOUGHT

P079 CWT. CHOICE HEIFER CALF SOLD

P080 CWT. CHOICE FED HEIFER SOLD

P084 CWT. MILK SOLD

P086 CWT. FEEDER PIGS BOUGHT IN OCTOBER

P087 CWT. FEEDER PIGS SOLD IN OCTOBER

P088 CWT. FEEDER PIGS BOUGHT IN DECEMBER

P089 CWT. FEEDER PIGS BOUGHT IN FEBRUARY

P090 CWT. FEEDER PIGS SOLD IN FEBRUARY

P091 CWT. FEEDER PIGS BOUGHT IN APRIL

P092 CWT. FEEDER PIGS SOLD IN APRIL

P093 CWT. FEEDER PIGS BOUGHT IN JUNE

P094 CWT. FEEDER PIGS BOUGHT IN AUGUST

P095 CWT. FEEDER PIGS SOLD IN AUGUST

P096 CWT. MARKET HOGS SOLD IN WINTER

P097 CWT. MARKET HOGS SOLD IN SPRING

P098 CWT. MARKET HOGS SOLD IN SUMMER

P099 CWT. MARKET HOGS SOLD IN FALL

P101 5 ACRE ROTATION OF C-SB-C-O-M ON LAND I

P102 5 ACRE ROTATION OF C-C-C-O-M ON LAND I

P103 4 ACRE ROTATION OF C-C-O-M ON LAND I

P104 5 ACRE ROTATION OF C-C-O-M-M ON LAND I

P105 5 ACRE ROTATION OF C-O-M-M-M ON LAND II

P128 DAIRY COW ON GRAIN AND HAY RATION

P129 DAIRY COW ON SILAGE, GRAIN AND HAY RATION

P140 BEEF COW ON PASTURE

P150 CHOICE STEER CALVES LONG FED ON PASTURE

P151 CHOICE STEER CALVES ON GRAIN AND HAY RATION

P152 CHOICE STEER CALVES ON SILAGE, GRAIN AND HAY RATION

P153 CHOICE YEARLING STEERS ON GRAIN AND HAY RATION

P154 CHOICE YEARLING STEERS ON SILAGE, GRAIN AND HAY RATION

P155 COMMON YEARLING STEERS ON GRAIN AND HAY RATION

P156 COMMON YEARLING STEERS ON SILAGE, GRAIN AND HAY RATION

P157 CHOICE HEIFERS ON GRAIN AND HAY RATION

P168 SOW AND TWO LITTERS FARROWED IN DECEMBER AND JUNE

P169 SOW AND TWO LITTERS FARROWED IN FEBRUARY AND AUGUST

P180 FEEDER PIGS STARTED IN DECEMBER

P181 FEEDER PIGS STARTED IN FEBRUARY

P182 FEEDER PIGS STARTED IN APRIL

P183 FEEDER PIGS STARTED IN JUNE

P184 FEEDER PIGS STARTED IN AUGUST

P185 FEEDER PIGS STARTED IN OCTOBER

P200 REAL ESTATE TAXES

P201 MACHINERY DEPRECIATION

P202 BUILDING DEPRECIATION

Rows for Demonstration Model

R01 HOURS WINTER OPERATOR LABOR AVAILABLE

R02 HOURS SPRING OPERATOR LABOR AVAILABLE

R03 HOURS SUMMER OPERATOR LABOR AVAILABLE

R04 HOURS FALL OPERATOR LABOR AVAILABLE

R09 HOURS WINTER LABOR TR.

R10 HOURS SPRING LABOR TR.

R11 HOURS SUMMER LABOR TR.

R12 HOURS FALL LABOR TR.

R13 WINTER CASH EXPENSES

R14 SPRING CASH EXPENSES

R15 SUMMER CASH EXPENSES

R16 FALL CASH EXPENSES

R17 WINTER LIVESTOCK PURCHASES

R18 SPRING LIVESTOCK PURCHASES

R19 SUMMER LIVESTOCK PURCHASES

R20 FALL LIVESTOCK PURCHASES

R21 ACRES LAND QUALITY I

R22 ACRES LAND QUALITY II

R24 CORN ACRES

R25 SOYBEAN ACRES

R26 OAT ACRES

R27 MEADOW ACRES

R29 CORN BU. HARVEST TRANSFER

R30 CORN SILAGE TR. TONS

R31 SOYBEAN TR. BU.

R32 MEADOW TR. HAY EQ. TONS

R33 HAY TR. TON

R34 PERMANENT PASTURE TR. TONS HAY EQUIV.

R35 FEED CORN TRANSFER BU.

R38 MILK TRANSFER CWT.

R39 CHOICE STEER CALF FEEDER TRANSFER CWT.

R40 CHOICE YEARLING STEER FEEDER TRANSFER CWT.

R41 COMMON YEARLING STEER FEEDER TRANSFER CWT.

R42 CHOICE HEIFER CALF FEEDER TRANSFER CWT.

R43 SUMMER CHOICE FED BEEF TRANSFER CWT.

R44 FALL CHOICE FED BEEF TRANSFER CWT.

R45 SPRING GOOD FED BEEF TRANSFER CWT.

R46 CHOICE FED HEIFER TRANSFER CWT.

R47 WINTER CHOICE FED BEEF TR. CWT.

R50 FEEDER PIG TRANSFER CWT. DECEMBER

R51 FEEDER PIG TRANSFER CWT. FEBRUARY

R52 FEEDER PIG TRANSFER CWT. APRIL

R53 FEEDER PIG TRANSFER CWT. JUNE

R54 FEEDER PIG TRANSFER CWT. AUGUST

R55 FEEDER PIG TRANSFER CWT. OCTOBER

R56 MARKET HOG TRANSFER CWT. WINTER

R57 MARKET HOG TRANSFER CWT. SPRING

R58 MARKET HOG TRANSFER CWT. SUMMER

R59 MARKET HOG TRANSFER CWT. FALL

R60 WINTER CASH RECEIPTS

R61 SPRING CASH RECEIPTS

R62 SUMMER CASH RECEIPTS

R63 FALL CASH RECEIPTS

R66 DAIRY COW CAPACITY HEAD

R67 BEEF COW CAPACITY HEAD

R68 FED BEEF CAPACITY HEAD

R76 HOG FARROWING CAPACITY LITTERS

R77 HOG FEEDING CAPACITY HEAD

R80 WINTER LIVESTOCK SALES

R81 SPRING LIVESTOCK SALES

R82 SUMMER LIVESTOCK SALES

R83 FALL LIVESTOCK SALES

R84 BREEDING STOCK INVESTMENT

R85 CAPITAL RESOURCE ROW

APPENDIX D

Coefficients Used in Demonstration Model

Listed by Activity and Restraint Number

P001	C	0.0
P001	R01	1.000000
P001	R09	-1.000000
P002	C	0.0
P002	R02	1.000000
P002	R10	-1.000000
P003	C	0.0
P003	R03	1.000000
P003	R11	-1.000000
P004	C	0.0
P004	R04	1.000000
P004	R12	-1.000000
P005	C	-1.500000
P005	R09	-1.000000
P005	R13	1.500000
P006	C	-1.500000
P006	R10	-1.000000
P006	R14	1.500000
P007	C	-1.500000
P007	R11	-1.000000
P007	R15	1.500000
P008	C	-1.500000
P008	R12	-1.000000
P008	R16	1.500000
P009	C	0.0
P009	R85	-1.000000
P010	C	-0.070000
P010	R13	-1.000000
P010	R85	1.000000
P011	C	-0.070000
P011	R14	-1.000000
P011	R85	1.000000
P012	C	-0.070000
P012	R15	-1.000000
P012	R85	1.000000
P013	C	-0.070000
P013	R16	-1.000000
P013	R85	1.000000
P014	C	-0.060000
P014	R84	-1.000000
P014	R85	1.000000
P015	C	-0.070000
P015	R17	-1.000000
P015	R85	1.000000
P016	C	-0.070000
P016	R18	-1.000000
P016	R85	1.000000
P017	C	-0.070000
P017	R19	-1.000000
P017	R85	1.000000
P018	C	-0.070000

P018	R20	-1.000000
P018	R85	1.000000
P019	C	0.0
P019	R60	-1.000000
P020	C	0.0
P020	R61	-1.000000
P021	C	0.0
P021	R62	-1.000000
P022	C	0.0
P022	R63	-1.000000
P023	C	0.0
P023	R80	-1.000000
P024	C	0.0
P024	R81	-1.000000
P025	C	0.0
P025	R82	-1.000000
P026	C	0.0
P026	R83	-1.000000
P030	C	0.0
P030	R24	-1.000000
P031	C	0.0
P031	R25	-1.000000
P032	C	0.0
P032	R26	-1.000000
P033	C	0.0
P033	R27	-1.000000
P036	C	0.0
P036	R66	-1.000000
P037	C	0.0
P037	R67	-1.000000
P038	C	0.0
P038	R68	-1.000000
P039	C	0.0
P039	R76	-1.000000
P040	C	0.0
P040	R77	-1.000000
P050	C	1.200000
P050	R29	1.000000
P050	R60	0.600000
P050	R61	0.600000
P051	C	-1.299999
P051	R14	1.299999
P051	R29	-1.000000
P052	C	0.0
P052	R29	1.000000
P052	R35	-1.000000
P053	C	-0.950000
P053	R11	0.500000
P053	R12	-0.120000
P053	R16	0.950000

P053	R29	5.599999
P053	R30	-1.000000
P054	C	2.700000
P054	R31	1.000000
P054	R61	2.700000
P055	C	-6.650000
P055	R10	1.200000
P055	R11	1.299999
P055	R14	2.500000
P055	R15	4.150000
P055	R32	1.000000
P055	R33	-1.000000
P056	C	18.000000
P056	R33	1.000000
P056	R62	18.000000
P057	C	-20.000000
P057	R13	20.000000
P057	R33	-1.000000
P058	C	-20.000000
P058	R16	20.000000
P058	R21	-0.500000
P058	R22	-0.500000
P060	C	15.000000
P060	R32	2.799999
P060	R62	15.000000
P061	C	-15.000000
P061	R15	15.000000
P061	R32	-2.799999
P062	C	6.650000
P062	R34	1.250000
P062	R62	6.650000
P063	C	0.0
P063	R32	1.000000
P063	R34	-1.000000
P070	C	-30.500000
P070	R20	30.500000
P070	R39	-1.000000
P071	C	28.750000
P071	R39	1.000000
P071	R83	28.750000
P072	C	27.500000
P072	R44	1.000000
P072	R83	27.500000
P073	C	-27.000000
P073	R20	27.000000
P073	R40	-1.000000
P074	C	27.500000
P074	R43	1.000000
P074	R82	27.500000
P075	C	27.500000
P075	R47	1.000000

P075	R80	27.500000
P076	C	-24.000000
P076	R20	24.000000
P076	R41	-1.000000
P077	C	25.500000
P077	R45	1.000000
P077	R81	25.500000
P078	C	-28.000000
P078	R20	28.000000
P078	R42	-1.000000
P079	C	27.000000
P079	R42	1.000000
P079	R83	27.000000
P080	C	25.500000
P080	R46	1.000000
P080	R82	25.500000
P084	C	4.500000
P084	R38	1.000000
P084	R80	1.690000
P084	R81	0.940000
P084	R82	1.120000
P084	R83	0.750000
P086	C	-36.000000
P086	R20	36.000000
P086	R55	-1.000000
P087	C	36.000000
P087	R55	1.000000
P087	R83	36.000000
P088	C	-36.000000
P088	R17	36.000000
P088	R50	-1.000000
P089	C	-36.000000
P089	R17	36.000000
P089	R51	-1.000000
P090	C	36.000000
P090	R51	1.000000
P090	R80	36.000000
P091	C	-36.000000
P091	R18	36.000000
P091	R52	-1.000000
P092	C	36.000000
P092	R52	1.000000
P092	R81	36.000000
P093	C	-36.000000
P093	R18	36.000000
P093	R53	-1.000000
P094	C	-36.000000
P094	R19	36.000000
P094	R54	-1.000000
P095	C	36.000000

P095	R54	1.000000
P095	R82	36.000000
P096	C	19.000000
P096	R56	1.000000
P096	R80	19.000000
P097	C	19.000000
P097	R57	1.000000
P097	R81	19.000000
P098	C	19.000000
P098	R58	1.000000
P098	R82	19.000000
P099	C	19.000000
P099	R59	1.000000
P099	R83	19.000000
P101	C	-124.000000
P101	R10	9.000000
P101	R11	6.200000
P101	R12	7.299999
P101	R13	7.500000
P101	R14	64.199997
P101	R15	7.900000
P101	R16	44.399994
P101	R21	5.000000
P101	R24	2.000000
P101	R25	1.000000
P101	R26	1.000000
P101	R27	1.000000
P101	R29	-185.000000
P101	R31	-28.000000
P101	R32	-3.000000
P102	C	-140.049988
P102	R10	10.799999
P102	R11	5.099999
P102	R12	8.599999
P102	R13	7.500000
P102	R14	61.899994
P102	R15	9.349999
P102	R16	61.299988
P102	R21	5.000000
P102	R24	3.000000
P102	R26	1.000000
P102	R27	1.000000
P102	R29	-265.000000
P102	R32	-3.000000
P103	C	-98.699997
P103	R10	7.700000
P103	R11	4.900000
P103	R12	5.900000
P103	R13	5.500000
P103	R14	47.099991

P103	R15	7.900000
P103	R16	38.199997
P103	R21	4.000000
P103	R24	2.000000
P103	R26	1.000000
P103	R27	1.000000
P103	R29	-185.000000
P103	R32	-3.000000
P104	C	-102.699997
P104	R10	7.700000
P104	R11	5.400000
P104	R12	5.900000
P104	R13	5.500000
P104	R14	50.099991
P104	R15	8.900000
P104	R16	38.199997
P104	R21	5.000000
P104	R24	2.000000
P104	R26	1.000000
P104	R27	2.000000
P104	R29	-180.000000
P104	R32	-5.799999
P105	C	-68.349991
P105	R10	4.599999
P105	R11	5.700000
P105	R12	3.200000
P105	R13	3.500000
P105	R14	38.299988
P105	R15	8.450000
P105	R16	18.099991
P105	R22	5.000000
P105	R24	1.000000
P105	R26	1.000000
P105	R27	3.000000
P105	R29	-90.000000
P105	R32	-8.400000
P128	C	-125.899994
P128	R09	30.399994
P128	R10	14.599999
P128	R11	17.199997
P128	R12	12.799999
P128	R13	54.000000
P128	R14	21.000000
P128	R15	27.000000
P128	R16	24.000000
P128	R33	6.000000
P128	R34	2.000000
P128	R35	65.000000
P128	R38	-110.000000
P128	R46	-2.549999

P128	R66	1.000000
P128	R84	490.000000
P129	C	-130.899994
P129	R09	30.399994
P129	R10	14.599999
P129	R11	17.199997
P129	R12	12.799999
P129	R13	57.000000
P129	R14	21.500000
P129	R15	27.000000
P129	R16	25.500000
P129	R30	7.700000
P129	R33	3.599999
P129	R34	2.000000
P129	R35	45.000000
P129	R38	-110.000000
P129	R46	-2.549999
P129	R66	1.000000
P129	R84	490.000000
P140	C	-21.000000
P140	R09	3.500000
P140	R10	3.000000
P140	R11	1.500000
P140	R12	0.500000
P140	R13	8.750000
P140	R14	4.419999
P140	R15	5.580000
P140	R16	2.250000
P140	R33	1.799999
P140	R34	3.799999
P140	R35	2.000000
P140	R39	-2.020000
P140	R42	-1.000000
P140	R46	-1.400000
P140	R67	1.000000
P140	R84	294.569824
P150	C	-22.099991
P150	R09	4.200000
P150	R10	2.299999
P150	R11	2.000000
P150	R12	2.500000
P150	R13	5.650000
P150	R14	4.150000
P150	R15	2.000000
P150	R16	7.549999
P150	R33	1.200000
P150	R34	1.299999
P150	R35	46.000000
P150	R39	4.500000
P150	R47	-11.250000
P150	R68	1.000000

P151	C	-26.439987
P151	R09	4.200000
P151	R10	2.099999
P151	R12	1.000000
P151	R13	10.750000
P151	R14	4.200000
P151	R15	5.700000
P151	R16	3.049999
P151	R33	0.800000
P151	R35	62.000000
P151	R39	4.500000
P151	R44	-10.500000
P151	R68	1.000000
P152	C	-27.939987
P152	R09	4.200000
P152	R10	2.099999
P152	R11	1.700000
P152	R12	1.799999
P152	R13	11.500000
P152	R14	4.200000
P152	R15	5.700000
P152	R16	3.799999
P152	R30	4.000000
P152	R33	0.300000
P152	R35	40.000000
P152	R39	4.500000
P152	R44	-10.750000
P152	R68	1.000000
P153	C	-21.409988
P153	R09	4.200000
P153	R10	2.200000
P153	R12	1.599999
P153	R13	10.900000
P153	R14	3.750000
P153	R16	5.049999
P153	R33	1.000000
P153	R35	60.000000
P153	R40	6.349999
P153	R43	-11.500000
P153	R68	1.000000
P154	C	-23.659988
P154	R09	4.200000
P154	R10	2.200000
P154	R11	0.800000
P154	R12	1.599999
P154	R13	11.400000
P154	R14	4.250000
P154	R15	0.750000
P154	R16	5.549999

P154	R30	4.250000
P154	R33	0.300000
P154	R35	40.000000
P154	R40	6.349999
P154	R43	-12.000000
P154	R68	1.000000
P155	C	-16.509995
P155	R09	4.200000
P155	R12	1.599999
P155	R13	8.349999
P155	R16	6.599999
P155	R33	0.800000
P155	R35	42.000000
P155	R41	6.500000
P155	R45	-10.250000
P155	R68	1.000000
P156	C	-19.509995
P156	R09	4.200000
P156	R10	0.400000
P156	R12	1.599999
P156	R13	10.349999
P156	R16	7.599999
P156	R30	3.250000
P156	R33	0.300000
P156	R35	30.000000
P156	R41	6.500000
P156	R45	-10.849999
P156	R68	1.000000
P157	C	-22.939987
P157	R09	4.200000
P157	R10	2.200000
P157	R11	0.800000
P157	R12	1.000000
P157	R13	10.549999
P157	R14	4.799999
P157	R15	1.500000
P157	R16	3.750000
P157	R33	0.800000
P157	R35	47.000000
P157	R42	4.200000
P157	R46	-8.700000
P157	R68	1.000000
P168	C	-90.699997
P168	R09	11.700000
P168	R10	5.799999
P168	R11	4.500000
P168	R12	1.000000
P168	R13	123.369995
P168	R14	33.549988
P168	R15	12.349999

P168	R16	21.429993
P168	R32	0.500000
P168	R35	64.000000
P168	R51	-2.599999
P168	R54	-3.000000
P168	R58	-3.299999
P168	R76	2.000000
P168	R84	77.000000
P169	C	-90.699997
P169	R09	11.700000
P169	R10	1.299999
P169	R11	9.000000
P169	R12	1.000000
P169	R13	35.299988
P169	R14	15.750000
P169	R15	29.099991
P169	R16	10.549999
P169	R32	0.500000
P169	R35	64.000000
P169	R52	-2.599999
P169	R55	-3.000000
P169	R59	-3.299999
P169	R76	2.000000
P169	R84	77.000000
P180	C	-7.174999
P180	R09	1.099999
P180	R13	7.174999
P180	R35	11.400000
P180	R50	0.400000
P180	R56	-2.200000
P180	R77	1.000000
P181	C	-7.174999
P181	R09	0.650000
P181	R10	0.450000
P181	R13	4.809999
P181	R14	2.360000
P181	R35	11.400000
P181	R51	0.400000
P181	R57	-2.200000
P181	R77	1.000000
P182	C	-7.174999
P182	R09	0.150000
P182	R10	0.750000
P182	R11	0.200000
P182	R14	5.740000
P182	R15	1.434999
P182	R35	11.400000
P182	R52	0.400000
P182	R58	-2.200000
P182	R77	1.000000

P183	C	-7.174999
P183	R10	0.350000
P183	R11	0.750000
P183	R14	2.400000
P183	R15	4.775000
P183	R35	11.400000
P183	R53	0.400000
P183	R58	-2.200000
P183	R77	1.000000
P184	C	-7.174999
P184	R11	0.650000
P184	R12	0.450000
P184	R15	3.849999
P184	R16	3.325000
P184	R35	11.400000
P184	R54	0.400000
P184	R59	-2.200000
P184	R77	1.000000
P185	C	-7.174999
P185	R09	0.450000
P185	R12	0.650000
P185	R13	3.325000
P185	R16	3.849999
P185	R35	11.400000
P185	R55	0.400000
P185	R56	-2.200000
P185	R77	1.000000
P200	C	-1.000000
P200	R13	0.500000
P200	R15	0.500000
P201	C	-1.000000
P202	C	-1.000000