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FARM ORGANIZATION AND RESOURCE FIXITY: MODIFICATIONS
OF THE LINEAR PROGRAMMING MODEL

By

Peter Edward Hildebrand

A THESIS

Submitted to the School for Advanced Graduate Studies
of Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1959

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AN ABSTRACT

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ABSTRACT

In this thesis, the standard formulation of the linear programming model is modified so that the productive resources of the firm are fixed endogenously rather than being arbitrarily fixed at a predetermined level. A resource is fixed for the firm if the acquisition price of another unit is greater than or equal to its marginal value productivity, which in turn is greater than or equal to its salvage value to the firm. Resource fixity in this model is subject to the above condition, the credit supply function of the firm, the initial level of the resource and the level of technology considered available to the firm.

In addition to the model, and in the absence of precise discrete programming procedures, a rule is devised for obtaining discrete investment levels for the resources acquired or sold in the solution. The rule is based on the concept of fixed assets incorporated in the model.

In the application of the model to a firm, the problem of varying the stock of durable resources and allocating the annual flow of their services is encountered because the objective of the analysis is to determine an optimum organization of the firm which maximizes annual net revenue. The acquisition and salvage values of the annual flow of services from a resource are regarded as the annual cost of ownership of the stock. The annual cost of ownership of a durable stock is the sum of the annual depreciation, interest, repairs and taxes on the resource.

The model is applied to a 160 acre South-central Michigan farm which is initially organized as a dairy farm with 32 cows and their replacements, a 32 stanchion barn meeting grade A market requirements and a full line of crop machinery. The model is sufficiently flexible to consider the following range of possible solutions: 1) selling the farm, investing the capital at 4 per cent interest and obtaining off farm employment; 2) a generalized dairy farm similar to the initial organization; 3) a milk-factory type of organization with all the feed purchased and 4) a cash crop farm with no dairy. Expansion of the firm is limited by the credit supply function of the farmer and a reasonable limit to the amount of land available for purchase.

The prices on items which can be purchased are 1958 prices uniformly inflated by 10 per cent. The prices received are $3.90 per hundredweight for milk, $0.90 per bushel for corn and $17.50 per ton for hay.

The final farm organization obtained from the model and the application of the rule for discrete investment levels, is a 320 acre cash crop farm with 13 acres of oats, 39 acres of hay and 216 acres of corn on the 268 tillable acres. The dairy was unable to compete with the cash crop alternative so the dairy herd was sold.

The model is constructed under the assumptions of static economic theory. As such, it does not consider the functions of management, situations of risk and uncertainty, nor formal and informal insurance schemes.

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CHAPTER I

INTRODUCTION

When the conventional linear programming problem is formulated with fixed restraints, the level at which the resources of the firm are fixed are of primary concern because these restrictions indicate the boundaries of the solution to the organizational problem of the firm. The linear nature of the profit function of the linear programming problem would indicate infinite production in the absence of these resource limitations.

To predetermine a set of fixed resources for any firm usually builds into the optimal solution a certain amount of unrealism. Many of the assets of a firm are not fixed in an economic sense, i.e., when the marginal value product lies between acquisition and salvage values. A farm firm is constantly adjusting many of the factors of production which are normally considered fixed in the usual formulation of the linear programming model for analyzing the resource allocation problems of the firm. Land is one of the most commonly fixed resources in programming an optimal operation of a farm. Many farmers, however, rent, buy and sell parts of farms or whole farms and recombine their land holdings. An important consideration in determining the optimum organization of a farm is to find the right amount of land to combine with the other factors. Similarly, all other factors are subject to acquisition and salvage and should be considered so in determining an optimum farm organization. In addition to the ability of the manager, important limits to farm size and organization involve the amount of funds over which the manager can gain control and some reasonable limit to the area in which land can be purchased.

A procedure allowing for variations in the initial asset structure of the firm, therefore, is the principal goal of this thesis--i.e., to determine a process whereby the resource restrictions in a linear program become endogenously determined. The procedure involves the use of increasing factor supply functions--primarily, that of the supply of credit--and a differential between acquisition and salvage prices of the factors. The approach involves essentially an increasing cost function for credit.

A problem which always exists in the interpretation of the results of a linear program involves the assumption of infinite divisibility of factors and products. Infinite divisibility is particularly a problem when considering investments in non-divisible assets such as tractors, silos, milking parlors and buildings. Some non-divisible assets such as tractors can be rented by time period and using such a method is satisfactory in certain problems. However, when investment in buildings and silos, etc. is being considered, renting in small units is undesirable or even impossible as a solution. An arbitrary rule for dealing with indivisibility in investments is developed and used in the thesis.

The Nature of Fixed Resources

In the most simple sense, fixed resources are those which cannot be or are not varied in quantity. In an economic sense, fixed resources are those which it does not pay to vary, i.e., those resources for which acquisition price is greater than or equal to marginal value product which is, in turn, greater than or equal to salvage value. In some cases, resources appear to be physically fixed. This could be the case for an old building, possibly constructed of stone or blocks or even of wood. It would appear that regardless of the MVP of such a building, assuming it to be very low, it would never pay to salvage it. This is an indication of a negative salvage value where a cost, greater than sale value, is involved in removing the building from the farm. Since it is not rational to produce where an MVP is negative, the building is, indeed, a fixed factor, even if it is not used at all. If the returns from the use of the land on which the building stands plus the sale value of the materials is greater than the cost of salvaging plus the MVP of the building, it would, of course, be salvaged. A factor is not fixed, then, if (1) the costs of removing it are exceeded by the sum of expected revenues occurring as a result of its salvage, or (2) the costs of acquiring it are exceeded by the sum of expected revenues occurring as a result of obtaining it. It is this principle which is used in constructing the model for this thesis.

Another form of fixity which may be effective are institutional restrictions. Acreage allotments may limit production of a given crop even though the MVP's of the factors in producing the crop exceed their marginal factor cost. Using wheat as an example, a combine may be fixed because no more than one is needed, even though its MVP may be greater than its MFC. The amount of credit which any firm can extend to an individual may also be limited by institutional restrictions. It is this type of restriction which partially determines the supply of credit available to a farmer.

<u>The Effect of Predetermined Resource Fixities Without Regard to MVP</u>

If a specific farm or "typical" farm is used as a basis for a linear programming problem, and the given resources are fixed at the initial levels, two types of error are likely to exist. A resource fixed in abundant amounts can be utilized to the point where its MVP drops to zero, indicating that salvage price is considered to be zero when it actually is greater than zero. The other extreme is a resource fixed in short supply. In this case, the MVP of the resource may be much higher than the MFC of another unit.

Both bases lead to a less than optimum allocation of resources. A factor fixed in abundance will cause the program to select inefficient technologies with respect to that factor. For example if labor is fixed in large amounts, labor saving technology becomes unimportant. Similarly, highly restricted factors will impose artificial requirements for technology favoring efficient use of this factor. If adjustment in factor quantity cannot be based upon the productivity of the factor, when, in fact no real barriers to adjustment exist, less desirable solutions will result.

The solution of a linear programming problem imputes values to the fixed resources. These values are the MVP of the resource to the firm--the amount of income which the firm would gain or lose by buying or selling, respectively, one unit of the resource. If the resources are artificially fixed, the imputed value would be unreasonable if that value were greater than acquisition price or less than salvage value. The true value of a factor to a firm is never less than its salvage value since the firm could realize at least this amount if it disposed of the factor in the market. Similarly, if the productivity is greater than cost of acquisition (MFC) the firm would gain by purchasing and using more of the asset.

A further undesirable characteristic of using fixed quantities of resources in optimizing a farm organization is that the stock of capital and credit is not converted into resources, but is used only for cash expenses for the completely variable or non-durable factors (factors for which cost of acquisition equals salvage value). In actuality, the stock of funds available to the firm is convertible into stock resources as well as factors comprising the list of expenses.

Endogenous Determination of Resource Fixity

A linear programming model incorporating the endogenous determination of resource fixity requires acquisition and salvage activities for all durable resources. The acquisition and salvage of durable assets presents a stock-flow problem since the use value of the asset during a time period is derived from the flow of services available c

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from the stock of the resource on hand. Short term profit maximization would undoubtedly involve the sales of all owned resources during the first time period. Therefore, it is essential that the stock price be appropriately distributed over the series of time periods during which its services would be available so that the costs from buying, and returns from selling, correspond to the time period involved in the flow of resources.

The costs of acquiring an additional unit of a durable asset for a one year period are the annual depreciation, interest, repairs and taxes. The sum of these four items rather than the market price is the annual marginal factor cost to the firm of acquiring the asset.[1] The corresponding annual salvage value to the firm of selling the asset is the sum of the depreciation, interest, repairs and taxes based on the salvage price of the asset at time of sale.

The MFC of a factor produced on the farm is the marginal cost of production to the firm, or the market price of the last unit delivered to the farm whichever is lower. So long as the MC is lower than the cost of purchasing the marginal unit, it will pay the firm to produce the factor if more is desired. When MC exceeds the cost of the marginal unit in the market, it will pay the firm to purchase the factor.

The imputed value of resources given in a model incorporating endogenous fixities will equal (1) annual cost of acquisition for all

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[1]For a fuller discussion of the pricing problem see footnote 1 on page 19.

resources increased in quantity, (2) annual salvage value for all resources decreased in quantity, or (3) the annual value in use for all resources fixed at the original quantity and neither purchased nor sold. Thus, all durable assets in this model receive an imputed value based on the annual flow of services from it.

Some Previous Linear Programming Models Incorporating Various Aspects of the Problem.

Many programming projects have been reported in the various Journals. Most of them follow the standard pattern with but slight variation. Two models which have been reported in the Journal of Farm Economics, while not closely related to the model developed here, incorporate some of the aspects of the problem under consideration.

Victor E. Smith[1] has constructed a model which incorporates a price differential between acquisition and salvage values for some factors and products. He incorporates cash and credit into a lump sum to which is added, in one model, the proceeds from hay sales. These funds are used to purchase feeder stock, protein supplement and corn but not labor nor shelter which, in addition to funds, are considered as fixed resources. In his second model the buying and selling prices of hay and corn are differentiated.

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[1]Victor E. Smith, "Perfect vs. Discontinuous Input Markets," Journal of Farm Economics, Vol. 37 (August, 1955), p. 538.

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Loftsgard and Heady[1] develop a model to obtain a solution over a series of years, ". . . with the optimum for any one year depending on the optimum in other years, on the availability of and returns on capital in other years, on the need for household consumption at different points in time, etc."[2] This model is of more interest as a suggested extension of the model developed in this thesis than as an explicit aspect of it and will be discussed in this respect in a later section. In their model, however, account is taken of investments added to the initial inventory of durable goods and includes expenditures for depreciation, taxes and insurance. They do not, however, include the problem of endogenous determination of resource fixity.

The Farm Situation and Credit Supply Functions

The farm to be programmed is a "typical" central Michigan dairy farm located on moderately productive soils (with Miami as the major soil series) containing 160 acres of which 132 are tillable. Included are a full line of equipment with a PTO forage chopper, two field tractors and one "chore" tractor, and a one row corn picker plus a 180 ton upright silo, a 32 stanchion barn which meets Grade A market requirements and 32 cows and their replacements. The silo is equipped with an unloader, but feeding is not automatic. It is considered that the milking routine is set up for average efficiency but the farmer is

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[2]Laurel D. Loftsgard and Earl O. Heady, "Application of Dynamic Programming Models for Optimum Farm and Home Plans," Journal of Farm Economics, Vol. 41 (February, 1959), p. 51.

[3]Ibid., p. 51.

capable of managing a highly efficient organization including automatic silage feeders and either a walk-through or a herringbone parlor.

Possible investments include new machinery of the same type already on the farm, additional upright silos or bunker silos, either a walk-through or herringbone milking parlor, additional bulk tanks, more cows and replacements, and automatic silage feeding bunks in the case of upright silos. Feeding from a bunker silo is on a self-feeding basis for efficient operation and the investment includes movable feeding gates for this purpose. In order to keep the farm an entity, that is, not spread over too wide an area, 480 acres is the maximum amount of land considered available for purchase. No limit is placed on the amount of the other resources which can be purchased except that imposed by the availability of spendable funds.

The debt-asset structure of the farm includes a total asset value of $45,090 with an estimated net worth of $36,000 and a debt of $9,090. The assets are $7,545 in machinery, $10,545 in cattle plus $3,000 in a bulk tank and $24,000 in land valued at $150 per acre. All initial debt was considered as land mortgage at 5.5 percent interest. The total amount of land mortgage available is 45 percent of current market value, $250 per acre, or $18,000. Deducting the mortgage outstanding leaves $8,910 of land mortgage available.

In addition to the land mortgage available, credit is available for purchasing the additional 480 acres of land. A 5.5 percent land mortgage is available for up to 160 acres, requiring a down payment of 55 percent. Two land contracts are considered available.

One contract requires 6 percent interest, the other 7 percent; both require only 10 percent down payment. Each contract can be used for as much as 160 acres purchased in 40, 80 and 120 acre units. A chattel mortgage is available for $10,545 which is half the value of the chattels and carries a 6.5 percent interest charge. The credit supply function also includes $20,000 at 13 percent from machinery dealers and $14,000 at 9.4 percent from a silo dealer. Real estate credit is payable over a 20 year period and all other sources of credit must be repaid in 3 years. Interest is charged annually.

Thesis Organization

First (Chapter II) the analytical model is presented and discussed. In Chapter III the problems of applying the model to the farm situation are discussed. The initial optimal solution, the succeeding solutions of the discrete investment series and the final farm organization are presented in Chapter IV. To simplify the material presented in the text, most of the technical data and results are listed in the Tables of Appendix B beginning on page 71.

CHAPTER II

THE ANALYTICAL MODEL

Many equations and activities in the model are of standard form, i.e., the type usually used in a resource allocation model as applied to a farm firm, and should require no clarification other than description. Labor from April to October inclusive is divided into monthly periods. November through March labor is considered one resource. Tractor services, measured in hours, are divided into the same monthly periods as labor. Machinery services are on a monthly basis and their availability is specifically taken into account only for those months in which they are required--there are no equations for equipment service during months when that service is not required. The unit for measuring machinery service is the number of acres which can be covered by that machine in an eight hour day, accounting for the number of days each month the land can be worked.

Since the unit of measure for the capacity of milking parlors is commonly time per cow, the services from the parlors are measured in 100 hour units. All other dairy equipment is measured on a per cow and replacement basis. Land is measured in tillable acres and all monetary equations are in $100 units. The crops produced on the farm are transferred into crop equations so that they either can be sold or fed to the dairy stock. In contrast, the milk production activities account for the sale of milk, since milk is not an input for other activities.

In constructing the model it was found necessary to include several specialized equations to handle satisfactorily, the investment activities. The asset acquisition and credit activities also require explanation since they contain some aspects peculiar to the model. Table 2.1 on page 22 should help clarify the following narrative.

<u>The Specialized Equations</u>

Some difficulty is encountered in explaining the three sets of specialized equations individually since there is a degree of relationship between them. However, as explaining them jointly would probably create confusion, they are explained individually, with some of the coefficients being more fully interpreted later in the chapter.

1. The "Sum" Equation. The name of this equation is unimportant and is not closely related to its function. The equation essentially states that the sum of the annual net revenue of the firm must be at least as great as the sum of all annual commitments which must be met if the farm is to remain solvent. Symbolically, omitting the variables: $\sum NR \geq \sum A_n C$. The annual commitments of the firm include those which accrue within the solution as well as any previous commitments the farmer has made or must pay such as taxes, debt repayment, depreciation and family living expenses. For convenience, let the sum of the initial annual commitments be called K. The equation then reads: $\sum NR \geq \sum A_n C + K$. The K becomes the restriction or b_i value: $\sum NR - \sum A_n C \geq K$.

To remove the inequality from the last equation a slack activity with the appropriate coefficient must be added.

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$$\lessgtr NR - \lessgtr A_n C - S_s = K$$

$$\lessgtr NR - \lessgtr A_n C - S_s + S_p = K$$

In these equations, S_s is the regular slack coefficient. A positive slack coefficient, S_p, must be added to complete the identity matrix used as the first solution in solving the problem by the simplex procedure. However, the positive slack activity, corresponding to the coefficient S_p, is artificial and should be prevented from entering the final solution. This artificial activity, therefore, requires an appropriate penalty coefficient in the objective function.

2. The Credit Source Restrictions (CSR). The model contains four of these equations, one for machinery dealer credit (CSRMD), one for silo dealer credit (CSRSD), and one each for land mortgage (CSRLM) and land contracts (CSRLC).[1] These equations are related to the acquisition of machinery, silos and land respectively, and state that no more of the particular source of credit is available than is generated by the purchase of that particular asset. For example, machinery dealer credit is not available unless, in fact, a piece of machinery has been purchased. The CSR for machinery dealers will serve as an example to explain the formulation of the equations.

It is necessary to pay 25 percent of the price (P) of a piece of machinery as down payment (Dp). Thus, machinery dealer credit cannot exceed 75 percent of the value of machinery purchased. It is important

[1]The abbreviations are used in Table 2.1 on page 22.

to note that purchase of machinery does not force the use of dealer credit. The purchase can be made wholly with cash. The equation, then, is:

Dealer credit available (DCA) $\leq$ P - Dp

or DCA - (P-Dp) $\leq$ 0

and removing the inequality:

$$DCA - (P-Dp) + S_s = 0$$

The DCA coefficient is part of the dealer credit acquisition activity and the P-Dp coefficients are in the machinery acquisition activities. The negative sign preceding P-Dp indicates that machinery acquisition increases the amount of credit available from this source by the amount of the coefficient. Since the initial restriction or b_i value is zero, no credit from this source is available unless machinery is purchased. The other CSR equations are exact duplicates of the CSRMD equation explained above except that the value of the down payment varies for each.

3. The Cash Equations. The model contains two cash equations. The first (Cash 1) is similar to the standard capital equation found in most programming models, with one exception. All funds acquired through the credit transactions are transferred into this restriction. Every credit acquisition activity increases the available supply of capital as expressed in the Cash 1 equation. In addition, all transactions and activities requiring cash draw the full amount involved from this equation. The cash expenses for the production activities

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are drawn from this equation as well as the full purchase price of all assets acquired.

The sales of assets increase the supply of funds since they will be sold at the beginning of the year, but the sale of products does not increase the amount of funds in Cash 1. Crop sales revenue is received after most of the expense for the farm has accrued. It would be unrealistic to add this income to cash to be used in its own production. An exception would be milk income which is generally received in monthly checks. In order to be realistic in adding this income to cash, it would be necessary to consider the capital restrictions by months. To consider monthly capital restrictions would involve a large amount of complication in the cash transfer and utilization activities. For this reason, income from milk production is not added to cash available for operation and asset purchase.

The second cash equation (Cash 2) concerns the minimum down payment required for any transaction. The acquisition activities involving all items which can be purchased with direct credit (machinery, silos, land) contain the down payment required, as a coefficient in this equation. The firm must have at least this much cash available before the purchase can be made. Since this equation involves only the actual cash available and not the total amount of funds, as does Cash 1, the credit activities such as land contracts which do not transfer cash, do not transfer funds into Cash 2. This is the major difference between the two cash equations. Cash 1 involves the total amount of funds the farmer has to work with including the full amount

of credit acquired from machinery dealers, silo dealers, from land mortgages and contracts. The Cash 2 equation considers only the actual cash the farmer has to work with. This amount of cash includes cash on hand and cash received from land and chattel mortgages only. In effect, the Cash 2 equation states that the money balance or cash on hand must be at least as great as the minimum amount necessary for purchase of the asset.

The minimum amount necessary for purchase of an asset is not always a down payment. Consider a bunker silo for example. The materials come from various sources, most of which do not offer credit plans. The usual procedure would be for a farmer to acquire a loan from some source either on his land or chattels and make cash purchases of the necessary material and labor. In this case, the coefficient in the Cash 2 equation is equal to that in the Cash 1 equation. And repeating, funds for purchases of this type are available from land mortgage and chattel mortgage acquisition activities.

One further aspect of the cash equations should be mentioned. Depreciation accrues to the firm as the products are sold. Since storable crops frequently are sold during the year following production, depreciation can accumulate at any time during the year. As an arbitrary choice, half the depreciation is added to the cash account at the outset. This makes it necessary to add half the annual depreciation of an asset to cash at the time of purchase, which is assumed to be at the first of the year. Similarly, half the depreciation must be removed from cash if the asset is sold. Therefore, for all depreciable assets, the full coefficient for the Cash 1 equation in the acquisition activities is price minus one-half the depreciation (P-1/2D). The corresponding coefficient for salvage activities is one-half of the depreciation minus the salvage value (1/2D-Vs).

The Double Purpose Acquisition Activities

Two methods exist for incorporating the asset acquisition activities into the model. The first, and less desirable involves, for each asset, one activity for cash purchases and one for purchases with direct credit. This would be necessary if only one cash equation were used since the two types of purchases require different amounts of cash.

The addition of the second cash equation reduces the number of activities needed by requiring only one acquisition activity for each asset. A single acquisition activity contains the coefficients for both cash equations and simultaneously handles both types of purchase. A direct credit purchase enters the solution only if one of the direct credit acquisition activities enters. If no direct credit acquisition activity has entered, all funds in both cash equations are derived only from cash on hand plus cash loan activities. Therefore, if none of the direct credit acquisition activities has entered, all purchases are on a cash basis and only the Cash 1 equation would be effectively limiting.

The extent of direct credit purchases which are made depends on the level at which the pertinent credit acquisition activities enter the solution. To this extent, funds are added to Cash 1 and not to

Cash 2, and both equations can then become effectively limiting. Thus, the type of purchase made, with cash or with direct credit, is independent of the acquisition activity and one activity serves a double purpose.

The Credit Activities

There are three types of credit acquisition activities in the model: mortgages, dealer credit and land contracts. Land mortgages are divided into two categories depending on use. A mortgage is available on the land owned by the farmer at 5.5 percent interest. This is one of the credit activities which transfers funds to both of the cash equations described above. The other land mortgage is available for purchase of up to 160 acres, the purchased land being the collateral. Since this latter activity does not transfer the actual funds to the farmer, only the Cash 1 equation is credited with the amount of the mortgage when the activity enters the solution. The land contract acquisition activities have the same effect on the cash equations as the second type of land mortgage activity since funds are not transferred directly to the farmer. A chattel mortgage acquisition activity is available and transfers funds into both cash equations. The two dealer credit acquisition activities, machinery dealer and silo dealer, affect the restriction of only the Cash 1 equation.

One additional credit activity should be described. This is the land mortgage repayment activity. The activity enters the solution only if the firm goes out of business, sells its assets and repays its

debts. Since no other debts exist at the outset, no other debt repayment activity need be considered. Funds are drawn from both cash equations if debt repayment is included in the solution.

The Cash Coefficients

The annual MVP of an asset must exceed the annual cost of ownership of one more unit of that asset (MFC) in order for the purchase of another unit to be profitable. The annual cost of ownership includes depreciation (D), interest (i), repair (R) and taxes (T). These items are, in effect, the cost of the annual flow of services from the asset. The sum of these items must be charged against the acquisition of an asset as the MFC of obtaining another unit.[1]

In this model, only the depreciation and taxes are charged directly against the acquisition activity for crop machinery; that is, appear in the profit equation as a cost coefficient. Repairs are charged as expenses in the crop producing activities since they are primarily a

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[1]The MVP and MFC can be in units of either a stock or a flow so long as both are in the same unit. To convert the MVP of a flow unit to the MVP of a stock unit, multiply the MVP by the number of flow units per unit of stock. The consequences of this relationship are explored in a later chapter.

The annual MFC of a stock unit is not the total market price of the resource divided by the number of years' use. A durable asset which has a life greater than one year, need not return its full market price in one year to be profitable to acquire. In contrast, the MFC of a unit of a non-durable item, which is expended within the year, is its market price--the equivalent of the annual cost of ownership of a durable asset. Since the annual cost of ownership of a durable asset is composed of depreciation, interest, taxes and repairs, these items comprise the annual MFC of a durable.

function of use. This cost is then reflected in the profit equation as crop producing cost. Charging repairs in this manner has the effect of reducing the direct annual MFC of the machine, but simultaneously, it increases the indirect cost by increasing the cost of producing the crop. Thus, indirectly, the MFC is unchanged. The annual expenses or "repair" charge on the livestock, i.e., veterinarian fees, breeding fees, etc., is similarly charged against the milk producing activities. Repairs on silos, buildings and dairy equipment are included with depreciation and taxes in the profit equation for acquisition activities.

All interest costs are handled through the credit acquisition activities. The initial cash on hand has an opportunity cost of four percent through the cash salvage activity. Capital used for production or asset purchase must bear a return greater than four percent before cash will be so used. When the initial cash on hand is exhausted, more can be acquired at 5.5 percent through the land mortgage acquisition activity. Therefore, the MVP of the asset purchased must be at least as large as the total of repairs, depreciation, taxes, and the interest charge, the latter being a cost coefficient in the profit equation for the credit acquisition activity. The profit equation coefficient for machinery sales activities reflects the savings to the firm of not owning the asset. That is, the depreciation plus taxes which are saved by not owning the machine.

The coefficients in the profit equation for the crop producing activities are cost figures equal to the cash expenses (CE) for non-durable items plus repairs on the durable assets. This same coefficient

is in both cash equations for these activities. The profit coefficients for the milk producing activities are gross revenue minus cash expense. The cash expenses appear in the cash equations. The profit coefficients for the crop sales activities are the gross revenues received from the sales since all costs have been deducted elsewhere in the program.

The sum equation accounts for changes in net revenue and annual commitments. The revenue increasing activities--milk production, crop sales, debt repayment and asset salvage--have the same coefficient in the sum equation as in the profit equation with a positive sign.[1] Asset acquisition activities increase annual commitments and thus bear a negative coefficient in the sum equation. Here, again, the coefficient is the same as in the profit equation as is the case for the coefficients in the crop producing activities which also have a negative sign. The annual commitment acquired upon the acquisition of credit includes not only the interest, but also the annual repayment of capital (C_R). The coefficient in the sum equation for the credit acquisition activities, therefore, is the sum of interest plus capital repayment and bears a negative sign since it is an annual commitment. The coefficients for the cash equations have been explained elsewhere.

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[1]Debt repayment actually is a cost decreasing activity, but the net effect is the same as a revenue increasing activity.

TABLE 2.1

CASH COEFFICIENTS FOR THE VARIOUS GROUPS OF ACTIVITIES

Activities / Equations	Land acq. cash or mort.	Land acq. contract	Machy. acq.	Credit acq. land mort.	Credit acq. land cont.	Credit acq. machy. dealer	Credit acq. land and mort.	Credit acq. banks (Chattel mort.)	Machy. sales	Credit repay-ment land mort.	Crop pro-duction	Milk pro-duction
Profit	-T	-T	-(D+T)	-i	-i	-i	-i	-i	(D+T)	i	-(CE+R)	NR
Cash 1	P	P	P-1/2D	-100	-100	-100	-100	-100	$1/2D-V_s$	100	CE + R	CE
Cash 2	.55P	.10P	.25-½D	-100				-100	$1/2D-V_s$	100	CE + R	CE
Sum	-T	-T	-(D+T)	$-(i+C_R)$	$-(i+C_R)$	$-(i+C_R)$	$-(i+C_R)$	$-(i+C_R)$	D+T	$i+C_R$	CE + R	NR
Land mort. avail.				100						-100		
Land cont. avail.					100							
Dealer credit avail.						100						
Bank credit avail								100				
CSRLM	-.45P						100					
CSRMD			-.75P			100						
CSRLC		-.90P			100							
Land and mort. avail.							100					

Specialization and Diversification and the Effect of a Single Fixed Resource on the Solution.

> . . . most farmers choose as their principal or main enterprise--around which to develop farming programs--an enterprise which has high and sustained marginal returns; they then produce this product with their fixed investment as long as marginal returns to the variable inputs exceed those obtainable from other enterprises. They add to such a crop (or livestock) other enterprises which will employ unused resources equally advantageously at the margin. If they are interested only in monetary returns, this process of expansion is continued until marginal returns are equal for all enterprises. . . . it is obvious that the existence of complementary (and, hence, multified farms) depends upon the production relationships existing for the variable factors of production, given the fixed investments in each enterprise. . . . if a high proportion of the inputs used in the production of the various products, is fixed, complementarity is likely to exist. If a small proportion of the inputs used in the production of the various products is fixed, then complementarity is less likely to exist.[1]

The basic assumption of this model, concerning initial resource fixity, is that the supply schedule for spendable funds is the only fixed resource. All other resources, except land to some degree, are variable and thus present no limit to production. The program, therefore, emphasizes, much as the farmer described in the above passage, the single most profitable activity relative to the use of spendable funds. The magnitude of this activity will expand to the point where the cost of obtaining additional factors of production, a function of the increasing cost of credit, exceeds the marginal value productivity of the factors in this one activity or to the limit of a resource, the MVP for which lies between acquisition and salvage values and is,

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[1]Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis (New York: John Wiley and Sons, Inc., 1953), pp. 171-172.

therefore fixed. This process of enterprise expansion can create idle services from some of the resources during the months in which they are not used. Such idle services might be used profitably in other enterprises or activities. In effect, these idle services have become fixed for the firm as a by-product of the expansion in resources to produce the most profitable product (activity).

An increase in the proportion of services which are thus fixed, tends to create seasonal complementarity (sometimes called supplementarity) between enterprises as expressed in the quoted passage above. Therefore, the program, as would the farmer, selects the next most profitable activity (enterprise) to make fuller use of the endogenously fixed stock of resources. Thus, it can be seen that specialization is not a by product of a single, fixed resource if provision is made for determining fixity endogenously. Unused services from endogenously determined fixed levels can make diversification a profitable alternative just as can unused services from predetermined resource fixities.

In a mechanical sense, it would appear that with only one resource initially fixed, only one production activity could enter the solution since in a standard linear programming model, when a resource becomes limiting, the slack activity becomes zero and a production activity enters the solution to the limit of the scarce resource. In the model presented in this thesis, a production activity can, but need not enter the solution when a non-money resource becomes limiting. If the productivity of the factor is such that more of the asset should be

purchased, an acquisition activity will replace the slack activity. Therefore, a production process or activity may not be obtained in the solution to replace a slack resource activity unless one of the resources is just exactly used up and no more acquired, i.e., the resource has been endogenously fixed at the initial level. However, since spendable funds are limited in amount, at least one production activity will enter so long as the solution indicates any production at all (the other possibility would be to sell out). Other possibilities for production processes to enter into the solution would be when any of the specialized equations (cash 2, sum or one of the CSR's) is an exact equality and the slack activity drops out. Thus, if it is profitable for the firm to diversify, the program, mechanically, is capable of arriving at such a solution.

Discrete Investment Levels

An ever present problem of linear programming evolves from the assumption of infinite divisibility. This problem is particularly difficult when considering investments in expensive durable items, since the purchase of a complete unit is essential. In this model an arbitrary method has been incorporated as one possible way of handling the problem.

The problem is to find the most profitable discrete level of investment for the important investment items. This is equivalent to the most profitable discrete level at which an asset should be fixed. Thus, the method evolved depends upon the concept of resource fixity.

An asset is fixed to the firm if its MVP lies between, or is equal to, its acquisition and salvage values. The greater the differential between the acquisition and salvage values, the more subject the asset is to fixity because the MVP will have to change by a greater magnitude before it lies outside these boundaries. It is also true that the MVP of a fixed asset will vary as the quantities of the variable factors used with it vary.

It is a reasonable approach to determine the level of fixity for assets individually, beginning with the one most subject to fixity. The variations of the other assets will be less likely to cause the MVP of the fixed asset to shift beyond the bounds of fixity if the one with the greatest differential between acquisition and salvage values is the first to be fixed in the solution.

The method, then, for determining discrete investment levels is first to obtain an optimal solution with all assets assummed to be infinitely divisible. Choose from among the assets in which investment occurred, the one most subject to fixity. This particular asset is then fixed for the farm at the next higher and next lower discrete level by changing the initial restrictions by the amount of the coefficients in the acquisition activity multiplied by the level of the activity for each case and removing the acquisition and salvage activities for the asset from the matrix. This process, however, may result in negative values for the restrictions in some equations, particularly the cash equations, so that manipulation of some other activity levels may be necessary to increase the negative values to some non-negative

or zero level. When this process is completed, the program is rerun twice, once for each investment level. After adjusting the profit values for each solution to account for the different investment levels, the solution for which the largest profit was obtained indicates the most profitable discrete investment level of the asset in question. The process is then repeated as often as desired, each time using the new set of restrictions derived from the previous trial solution.[1]

Figure 1 should help explain the procedure described above. In Figure 1, ACGK is a portion of the MFC curve for spendable funds and the point E represents the MVP of dollars invested for the optimum solution. To the left of E, the MVP of cash would be no lower than DE, and to the right, no greater than EF. The line DEF, therefore, represents the extreme range of the MVP of cash on either side of the optimum value, E. The initial optimal solution indicates the use of OP dollars of inputs including an investment in 2.4 tractors with a revenue of OREP or greater. The problem is to determine whether an investment in two or in three tractors is more profitable.

If investment is fixed at two tractors, revenue will be no less than the area ORDN, the area lying under the MVP curve. The net cost of moving from 2.4 to 2 tractors is BDEC, the loss in net revenue. Net revenue, of course, is $\leq$ MVP-$\leq$ MFC or BDEC between 2 and 2.4 tractors. In moving from 2.4 to 3 tractors, the net cost is EGHF, the

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[1]It should be emphasized that this method of determining discreteness leaves much to be desired. See Appendix A for a more complete discussion of the effect on resource fixity from using this method.

amount by which the change in cost exceeds the change in revenue. The alternative chosen is the one having the lower net cost--two tractors would be chosen if the relationships were as in Figure 1.

The difficulty is in determining the magnitude of the net cost areas BDEC and EGHF. The effect of forcing an investment in either two or three tractors can change the proportions in which the enterprises as well as the inputs are combined. This can cause a shift in either or both the MVP and MFC such that it is impossible to predetermine, without computing the two programs, the most profitable level of investment for the asset under consideration.

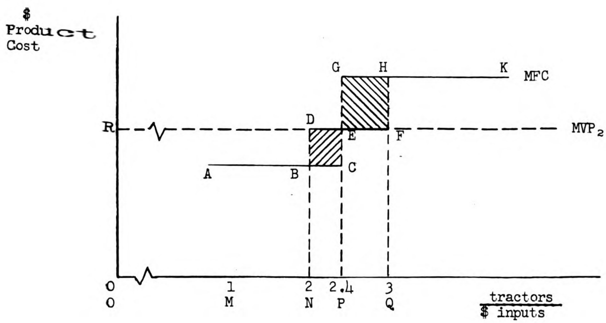

Figure 1

CHAPTER III

APPLICATION OF THE MODEL

The model was applied to a "typical" central Michigan dairy farm situation for which several alternative organizations were considered. The "typical" aspects of the farm refer to the initial resource base including type of land, amount and kind of machinery, size of herd and livestock facilities. The manager was considered to be above average in capabilities for obtaining higher than average crop and milk yields and able to use the most efficient type dairy facilities in use at the present time. The dairy farms of Michigan are presently undergoing a technological change, increasing labor efficiency particularly for the milking chores and herd management. Therefore, it is not unreasonable to consider such possibilities for a man on an average dairy farm.

Crop Production

In all, 33 crop producing activities are included in the model, involving three crops--corn, oats and alfalfa. The oats and alfalfa are considered as one crop with one-fourth of each acre devoted to oats, for a nurse crop, and three-fourths to alfalfa. The proportion of corn in the rotation is independent at all levels. The solution could involve continuous corn, no corn, or any amount in between. For each crop, three fertilizer levels are included, the lowest level being about equivalent to the general level of application currently in practice. Consequently, the higher fertilizer levels are concurrent with above average management practices.[1]

Silage is an important component of the rations for dairy cattle. It is desirable, therefore, to include in a dairy farm program, various amounts of both hay and corn which can be cut for silage. The amount of corn cut for silage varies by 20 percent intervals from zero to one-fifth, to two-fifths, up to 100 percent. The oats are all cut for silage in each oat-hay activity, with the combined oat-hay crop being cut for silage at the rate of one-fourth (oats only) two-fifths, three-fifths, four-fifths and 100 percent. Thus, there are six corn production activities and five oat-hay activities each having three levels of fertilizer application, or a total of 33 crop production activities.

Milk Production

Initially, the farm is equipped with a 32 stall grade A stanchion milking barn and a 500 gallon bulk tank. Milking is done by machine, but the milk is carried to the bulk tank. Grain is fed on an individual basis from a cart. Silage feeding is accomplished with an automatic

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[1]The low and medium fertilizer application levels are taken (with slight modification) from: C. R. Hoglund and R. L. Cook, Higher Profits From: Fertilizer and Improved Practices, Agricultural Economics Mimeo 545, Michigan State University Agricultural Experiment Station and Soil Science Department, Revised October, 1956. The high application levels are a current revision of the same publication by Hoglund, Cook, John Guttay and L. S. Robertson.

silo unloader in the upright silo but without automatic auger feed bunks. The labor efficient operation of the stanchion system includes an automatic feeder for silage and a pipe line milking system. If the herd were expanded or more silage fed, additional investments could include another upright silo or bunker silo. Three stanchion systems are considered as alternatives in the model: the present system with "average" labor efficiency; a labor efficient system with upright silos; and a labor efficient system with additional investment in one or more bunker silos.

Two milking parlors are included--a double three walk-through parlor and a double six herringbone system. For each type, combinations for (1) "average" efficiency with upright silos, (2) efficient operations with upright silo and (3) efficient operations with bunker silos are included. In addition, for each of the nine different systems, nine rations with varying proportions of hay and silage and varying levels of grain are used. There are three proportions of hay and silage with three grain levels for each. Milk production increases from 10,000 pounds to 10,500 pounds and 11,000 pounds depending on the amount of grain in the ration. In all, the model contains 81 different milk production activities.

Derivation of the Technical Matrix and Restrictions

Technical production data for a specific area are always difficult to obtain. The sources of data used in this thesis are primarily published bulletins and articles and unpublished reports of the Michigan

Agricultural Experiment Station. Where specific data were not available, "best-estimates" were obtained from staff members working in that field. Tables summarizing the data used are presented in Appendix B.

The restrictions for all crop machinery except tractors are computed for the number of acres which can be covered in an eight-hour day including time loss for repairs, lubrication and turning. An estimate of the number of days per month during which field conditions are suitable for field work was used to obtain the total number of acres which could be covered per month for each operation. Tractor services are based on an eight hour day and are considered available the same number of days per month for which field conditions are satisfactory. The data used in the computations are in Appendix B.

The capacity of the milking equipment was figured in hours for 16 hours a day, 365 days a year. This would make possible a specialized "milk factory" operation. Since the milk production activities are on a per cow basis, the coefficients are the number of hours per cow per year, milking at the rate of 46 cows per hour for the most efficient parlor organization. The feeding equipment is on a per cow basis, so that the coefficients are one.

Acquisition and Salvage

All the crop producing machinery can be bought or sold. A differential between acquisition and salvage prices makes it unprofitable to buy and sell the same piece of machinery. Land, too, can be bought or sold. If the original acreage is sold, the mortgage on it must be repaid. The acquisition of a new milking parlor includes the disposal of the old stanchion barn. Buildings and facilities which are not included in the initial resource base cannot be sold so no salvage activity exists for these items. In addition, more cows and replacements, jointly, can be purchased, or any proportion of the herd sold.

Hired labor can be acquired by the month for cropping operations and summer milking for the months of April through October. Any labor acquired during the off season would be for milking, so the months of November through March are grouped together. In case no dairy is included in the solution, the farmer has the opportunity of off-farm employment of his labor during the slack months of November through March. The opportunity cost of the farmer's own labor during the summer months is the possibility of employment a specified number of days every month up to full time off-farm employment.

<u>The Range of Possible Solutions</u>

First, it is possible for the farmer to sell out completely, invest the resulting cash at 4 percent, and obtain full time off-farm employment. The earnings from off-farm employment will satisfy the family living requirements and thus, the sum equation, since all other annual commitments will be cancelled. It is also possible to have a complete milk factory with all inputs acquired. It is possible to purchase all labor, feed and equipment necessary to run this type of operation. The third possible extreme is to keep the farm but sell

the dairy equipment and herd and end up with a cash crop farm. It is not necessary for the crops to be sold through the dairy herd.

Given these extremes and the assumptions of linear programming, it is evident that any combination of the limited number of alternatives considered, represents a possible solution.

CHAPTER IV

SOLUTION OF THE FARM MODEL

The initial optimal solution obtained from this model is unique to linear programming in that the quantity of all resources can be varied should it be profitable to do so. Consequently, the model allows the determination not only of the optimum combination of enterprises, but also the optimum combination of the factors of production subject to the limitation on funds, the initial asset structure, the acquisition and salvage values of the assets, product prices and the input-output relationships. Since the principal limit to enterprise organization and size results from the increasing cost of obtaining funds, the solution is optimal with respect primarily, to spendable funds. In addition, the imputed values of the resources are a function of their acquisition and salvage values, their use opportunities and their initial level on the farm, rather than being a function of an arbitrarily set and rigidly fixed limitation on the amount available to the farm.

The Initial Optimal Solution

The initial assumptions made in formulating the model result in an optimum organization consisting of a 337.2 acre cash crop farm containing 282.7 acres of continuous corn, of which 12 acres are cut for silage and sold out of the field, with the remainder sold as grain.

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This organization involves the purchase of 177.2 acres of land, of which 85 percent is assumed to be tillable, and the complete disposal of the dairy enterprise. Although somewhat unrealistic, it is more profitable for the farmer to take advantage of full-time off-farm employment and hire the necessary farm labor.[1] Table 4.1 shows the change in inventory between the initial farm assets and those of the optimum organization.

TABLE 4.1

ORIGINAL AND OPTIMUM INVENTORIES

Item	Initial Inventory	Purchased	Sold	Optimum
Land, total acres	160	177.2		337.2
Land, tillable acres	132	150.7		282.7
Dairy cows	32		32	0
Dairy heifers	11		11	0
Dairy calves	13		13	0
Field tractors	2	3.0		5
Plows	1	1.6		2.6
Disc, drill	1		1	0
Disc, planter	1	1.1		2.1
Cultivator, sprayer	1	0.7		1.7
Mower, rake	1		1	0
Wagons	2	4.8		6.8
Chopper	1		0.8	0.2
Fertilizer spreader	1		1.0	0
Corn pickers	1	2.4		3.4
Bulk tank	1		1	0

[1]In at least one case, this has actually occurred on a Michigan farm. In general, however, this is an undesirable course of action since it leaves the farm without an active manager when only monthly labor is hired. Were the hired labor on a full time or tenant basis, of course, the organization would not be unrealistic nor necessarily undesirable. Obtaining such a result in the solution is a consequence of the static nature of the analysis. The opportunity cost of full time off farm employment is sufficiently high that, since management is not considered a necessary resource, the services of the manager are sold off the farm.

After deducting cash expenses, taxes, depreciation and interest for new debt, but excluding interest on the owned assets and capital repayments to retire the debt, profit for the optimum solution is $8810.[1] Deducting the off farm income of $4500 leaves a farm profit of $4310. Farm profit includes a return to owned assets. If the owned capital is charged a 6.5 percent interest rate, which is the highest rate paid for credit, the remaining amount is $2412.

Adding the off farm income to the $2412 above gives the labor income for the farm. Labor income is $6912. If the family spends only the minimum amount for consumption, $3200, then $3712 is available from labor income to retire the debt. The annual capital repayment contracted upon the acquisition of the debt is $3635. By paying this amount in full, the family has available for consumption, in addition to the minimum $3200, the amount of $77.[2]

To organize the optimum farm requires a full mortgage on the owned land and a chattel mortgage on all equipment. In addition, 160 acres is purchased with a 6 percent land contract and an additional 17.2 acres with a mortgage after meeting the down payment requirements. The total annual interest and capital repayment commitment which the farm must meet is $7320. In addition to the credit acquired, cash was increased $8837 by the sale of assets.

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[1]This is the value which is maximized in the objective function. For purposes of comparing profit from the various solutions, only those items stated above are deducted from gross income. This figure could be called return for family labor and owned capital.

[2]It is, of course, possible for the family to spend for consumption the interest on owned assets and depreciation, in addition to labor income.

The values imputed to the resources and farm produced crops are of major interest from both an empirical and a theoretical point of view. As one would expect on a cash crop farm where the crops are not sold through livestock, the value of the crops are the prices received by the farmer--90 cents per bushel of corn and $17.50 per ton hay equivalent of silage. Similarly, the imputed value of assets sold should be equal to their salvage value.

The salvage value of a unit of service from a durable asset is equal to the savings in depreciation, taxes and interest all based upon the salvage value of the durable stock. For example, the depreciation and taxes per cow and replacements as a unit are $42.39. The interest charged at the highest rate (6.5 percent) on the net salvage price of $139.22 is $9.05. The Delta J value or imputed value of the cow and replacements unit is $52.07 which is very near the total of taxes, depreciation and interests, $51.44.[1] The imputed value of one unit of service from the disc, drill asset is 80 cents. The salvage value of the service unit is 79 cents. The corresponding values for the forage chopper, which was only partially sold, are $3.52 and $3.47 respectively.[2]

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[1]The term Delta J stands for the imputed value of the activities. The values imputed to the slack activities are the MVP's of the resources. An accumulated round-off error, accounting for the difference between the Delta J and salvage value is to be expected when working with a large number of equations and activities, especially with the high degree of interaction expressed in this model.

[2]The MVP's of the resources are expressed in terms of the units in which they are measured. In the cow and replacements example above, both the salvage activity and the resource are measured in the same unit. In contrast, machinery salvage is measured in terms of a stock but the resource in terms of a flow of services. (As a consequence, such resources are varied in terms of a flow rather than in terms of a stock.) Therefore, it is necessary to divide the salvage value of such an asset by the number of units of the flow service derived from it to put it in the units in which the imputed value is measured.

The acquisition cost of a unit of flow service from an asset is the sum of the annual cost of depreciation, interest and taxes of the stock divided by the number of flow units. This cost is computed in the same way as was the salvage value for assets sold. The imputed value and cost of acquisition respectively for three acquired resources are: for May plow services, \$.34 and \$.29; the services for the disc and corn planter, \$.67 and \$.63; and an hour of June labor, \$1.44 and \$1.43. A listing of the imputed values of the resources for each solution appears in Appendix B and are further discussed in a later section.

The values imputed to non basis or excluded activities indicate the decrease which would occur in profit if that activity were forced into the solution.[1] This information makes possible the determination of the relative profitability (in a more strict sense, unprofitability) of those activities not in the solution. Several aspects of the excluded activities are worthy of note.

Considering first, the corn activities in which all the corn is picked for grain, the activity having the heaviest level of fertilization entered the solution. The reduction in profit from using the medium level of fertilizer would have been \$19.60 an acre, determined from the Delta J value of the activity. Using the lightest application of fertilizer considered in the program would have reduced profit by \$44.12 per acre. The same relationship is true for all the corn

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[1]Non basis activities are the activities which do not enter into the final solution.

activities. That is, the heavier the application of fertilizer, the less would be the reduction in profit or, stated alternatively, the greater the increase in profit, from incorporating that activity in the solution. Within the corn activities using a high level of fertilization, the reduction in profit from increasing the amount of silage would be $3.24 per acre if 40 percent were so harvested, $4.78 if 60 percent, and $6.40 and $8.04, respectively, for 80 and 100 percent silage per acre.

No hay producing activities entered the solution. The least reduction in profit from forcing hay into the solution ($1.88 per acre of hay) would have resulted from the most highly fertilized hay of which only the oat nurse crop was chopped for silage. Here, again, the increasing reduction in profit from decreasing the level of fertilization is evident as well as from increasing the amount of silage per acre.

By varying the level of fertilizer within a crop activity series with the proportion of silage held constant, the change in profit due to changing the fertilizer can be determined. For example, consider the corn activities in which 40 percent of the acreage was chopped and 60 percent picked. The imputed values of the activities at the three fertilizer levels were: low, $21.20; medium, $10.88 and high, $3.26. Since these figures indicate the loss in profit, the difference between low and medium, and between medium and high indicate the increase in profit from heavier applications of fertilizer. The gain in profit from low to medium is $10.32 and from medium to high is $7.62. Plotting these values on a graph with dollars of fertilizer on the horizontal axis, illustrates the decreasing returns as more fertilizer is applied.

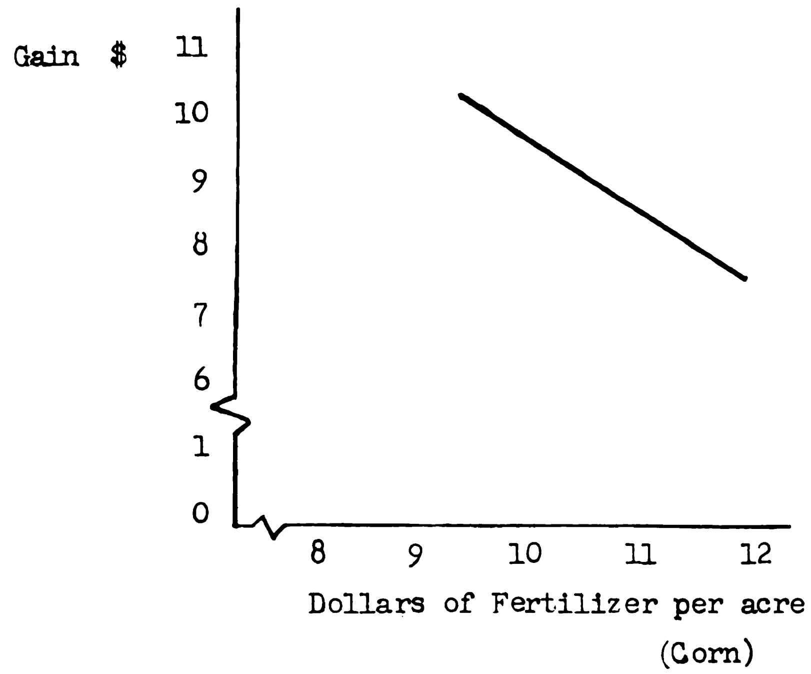

Figure 4.1

Since in the imputed values, all costs are accounted for, the values plotted in Figure 4.1 are changes in net revenue or profit and can be defined as gain. Maximum profit is equivalent to zero gain. Therefore, it appears that even though higher level fertilizer applications were used in this study than currently in common practice, even higher applications would be profitable. The total cost of fertilizer applied to corn at the three levels was: $8.32, $10.42 and $12.92.

The total cost of fertilizer applied to hay at the three levels was: $3.40, $6.54 and $9.32. The corresponding imputed values for hay with only the oats cut for silage are $21.94, $11.28 and $1.88.

In Figure 4.2, the gain obtained from increased fertilizer application is plotted. Here, again, it appears that heavier rates of fertilizer would be profitable.

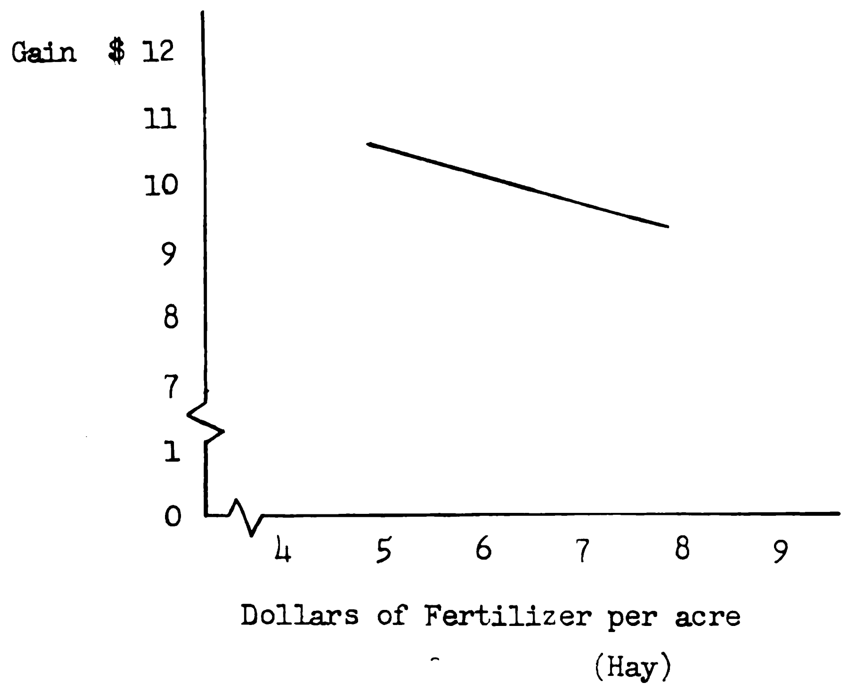

Figure 4.2

With only two points on the gain function, it is not possible to determine the most profitable level of fertilizer to use. However, the closer gain is to zero, the closer the rate of application to the maximum profit point. Given the information available, it appears that the rate of fertilizer application on corn is nearer to the optimum than the rate on hay.

The magnitude of the Delta J values for the milk producing activities indicate that dairying, under the conditions set forth in the assumptions, is a poor alternative compared to cash cropping if continuous corn is possible. The least unprofitable type of dairy

enterprise, a highly labor efficient herringbone system, would have reduced profit by $2224 if one cow were milked. Throughout all three milking systems, efficiency in labor utilization has a marked effect on profitability, but there is only a slight profit differential between upright silos and bunker silos. In choosing between the types of milking parlors, the double six herringbone has a slight advantage over the double three walk-through, but investing in either would be considerably more profitable (less unprofitable) than using the stanchion arrangement already on the farm.

The Discrete Investment Series

Had a dairy enterprise been included in the solution, the important assets for which to determine discrete investment levels would have been the milking parlor and the silos. These are items with a high acquisition cost and, because of their permanent nature, a relatively low salvage value.

On a cash crop farm, it is important to determine the size of the farm, the number of tractors, and the amounts of other expensive machinery. In addition to determining the level of land and tractor investments, solutions were obtained to determine whether or not to sell the forage chopper and to find the most profitable number of corn pickers for the farm.

Fixing the level of any asset for the farm, will decrease the value of the objective function from the previous solution in which the asset level was not fixed. Each successive solution, therefore, for which more and more of the assets are fixed will have a lower profit than the previous solution. That is, the solutions for a resource fixed at the next higher and next lower discrete levels, will both exhibit less profit than did the previous solution.[1] The choice of which discrete level of investment to use depends on the relative profitability between the two levels being programmed.

Forty acres was considered as the most reasonable discrete level of land investment. Forty acre plots are generally available while an area as small as 20 acres is not. To restrict purchase to 80 acres puts an unreasonable demand on farm size. The initial solution indicated an investment in an additional 177.2 acres or 337.2 total farm acres. Land investment programs were computed, therefore, for 320 and 360 total acres or for an additional investment in 160 and 200 acres. The optimum organization and profit for both conditions is given in Table 4.2 on the following page.

The 320 acre farm incorporates 268 acres of continuous corn and no hay. Twelve acres of corn is chopped for silage using the services of 0.17 chopper. An additional 2.2 corn pickers are acquired to pick 256 acres of corn, and the acquisition of 2.7 tractors increases the stock of tractor services to 4.7 tractors. The addition of 40 acres, giving rise to the 360 acre farm, makes hay production a profitable alternative by decreasing the necessary investment in specialized corn

[1]It should be pointed out that the higher profits received from prior solutions are based on infinite divisibility of factors and product and as such, are only illusionary.

TABLE 4.2

PROFIT AND ORGANIZATION FOR 320 ACRES AND 360 ACRES

Description	320 Total Acres	360 Total Acres
Tillable acres	268	302
Tractors, beginning inventory	2	2
Tractors acquired	2.7	2.0
Tractors, ending inventory	4.7	4.0
Choppers, beginning inventory	1.0	1.0
Choppers sold	0.83	0.53
Choppers, ending inventory	0.17	0.47
Corn pickers, beginning inventory	1.0	1.0
Corn pickers acquired	2.20	1.84
Corn pickers, ending inventory	3.20	2.84
Acres in hay, high fert., oats for silage	0	74.8
Acres in corn, high fert., 1/5 for silage	60.0	1.4
Acres in corn, high fert., all picked	208.0	225.8
Total acres, picked corn	256.0	227.0
Profit, nearest dollar	$8345.00	$7639.00
Profit differential	+706	

equipment. The production of 74.8 acres of hay restricts corn production to 227.2 acres. With fewer acres in corn, a smaller tractor investment is required since the use of tractor services is spread more evenly throughout the year. Since all the hay is chopped as well as the oat silage, more chopper services are retained on the larger farm. Profit comparison between the alternative organizations, however, favors the smaller farm. Consequently, succeeding programs are based on 320 acres.

The MVP's of most resources were reduced only slightly, comparing the 320 acre farm with the initial optimal solution. As would be expected, however, the MVP of land increased (from $20.72 per acre to

$22.11 per acre) when it was fixed at the 320 acre level. Cash, which in the initial optimum was worth $7.42 per $100, is worth $6.50 per $100 on the 320 acre farm. This occurs as a result of the limitation on land, which causes some 6.5 per cent credit not to be used.

In Figure 4.3, the segmented curve labeled AB·CD·EF represents, again, a portion of the MFC of dollars to the firm and the line MVP indicates the MVP of spendable funds in the initial optimum solution.

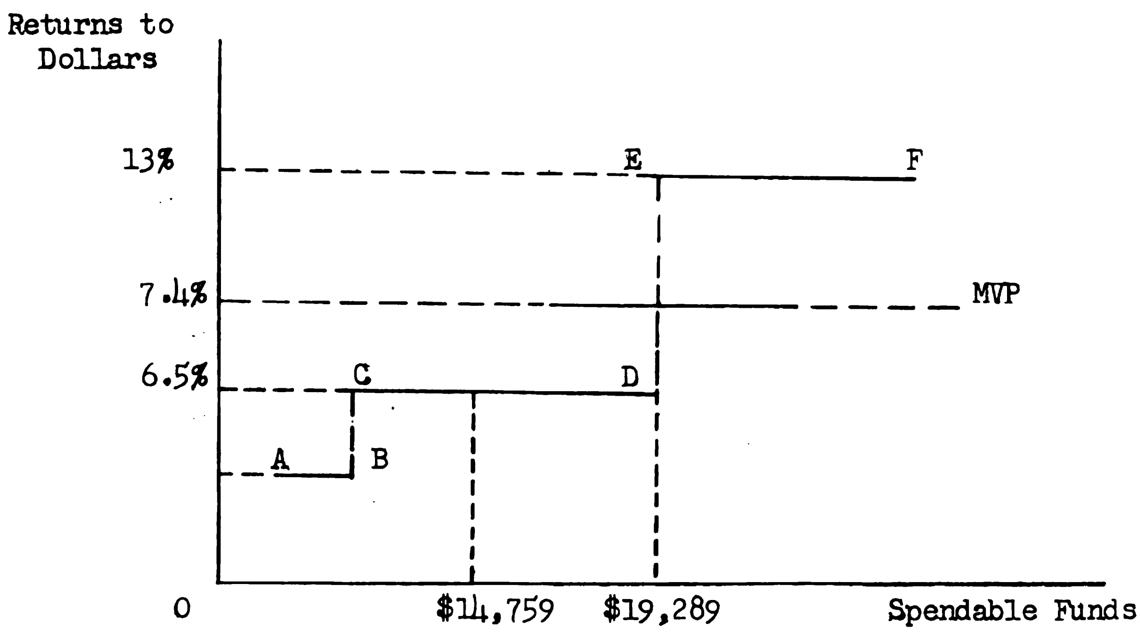

Figure 4.3

Spendable funds, here, includes cash, owned land mortgage and chattel mortgage, but not land contract funds nor land mortgage on purchased land. In the optimal solution, a total of $19,289 of spendable funds was used. This amount includes all the 6.5 percent credit available. In the 320 acre organization, the land limitation forced down the MVP of spendable funds so that not all the 6.5 percent credit is exhausted.

Were the MVP of spendable funds greater, an additional $4530 of 6.5 credit could be acquired.

The 320 acre organization indicated an optimum of 4.7 tractors. Programs were computed to determine the most profitable alternative between 4 and 5 tractors. The results appear in Table 4.3.

It is of interest to note the effect on organization from fixing the number of tractors at levels higher and lower than the optimum number in the previous 320 acre solution. Restricting the number of tractors to four has the expected effect of placing a premium on their services, and as a result, more intensive use of these services through time is required. Although hay is a less profitable crop than is corn, it is profitable to more fully utilize these tractor services than to specialize in the production of corn. Specialized corn production makes less efficient use of the relatively scarce tractor services than does the more diversified previous solution.

The farm organized around five tractors is a sharp contrast to the one for which tractors are a more limiting resource. On the five tractor farm, tractor services are relatively abundant. As a consequence, intensification of their use is not a prerequisite to a profitable farm organization, as is the case where tractor services are relatively scarce. Because tractor resources are fixed at a high level on the second (five tractor) farm, specialization is a profitable alternative.[1]

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[1]The comparison of these two programs with reference to the effect of tractor limitation on organization is a good example of the effect on the ultimate outcome from predetermining the level of resource fixity.

Although the second farm specializes in a relatively more profitable crop, the added expense of the additional tractor is sufficient to reduce profit below that for the four tractor farm organization. Since the four tractor farm is more profitable, it is this organization which was chosen for further investigation in accordance with the rule developed for this purpose. In an actual planning situation, however, the profit differential is sufficiently small that other alternatives should be considered.

TABLE 4.3

PROFIT AND ORGANIZATION FOR 320 ACRES WITH 4 AND 5 TRACTORS

Description	Four Tractors	Five Tractors
Tillable acres	268	268
Tractors	4	5
Choppers, beginning inventory	1	1
Choppers sold	0.8	1
Choppers, ending inventory	0.2	0
Corn pickers, beginning inventory	1	1
Corn pickers acquired	1.82	2.35
Corn pickers, ending inventory	2.82	3.35
Acres in hay, high fert., oats for silage	2.80	0
Acres in corn, high fert., 1/5 for silage	71.1	0
Acres in corn, high fert., all picked	168.9	268
Total acres, picked corn	225.8	268
Profit, nearest dollar	$8228.00	$8088.00
Profit differential	+140	

The question of whether or not to sell the forage chopper is the next to be determined. The 4 tractor optimum indicated salvage of 0.8 of the chopper, using only 0.2 to harvest 28 acres of hay and 14.2 acres of corn silage. If the chopper is completely sold, only ear corn can be raised since both the hay and corn silage activities require the services from the chopper and no provision is made for hiring custom work on the farm. If the chopper is not sold, one would expect a more diversified farm plan to make fuller utilization of this fixed, specialized piece of equipment. In some respects, therefore, the effects of selling or keeping the chopper are more important to the farm organization than determining the level of fixity for the resources with a more general use.

TABLE 4.4

PROFIT AND ORGANIZATION FOR 320 ACRES, 4 TRACTORS, WITH AND WITHOUT A FORAGE CHOPPER

Description	Without Chopper	With Chopper
Tillable acres	268	268
Tractors	4	4
Chopper	0	1
Corn picker, beginning inventory	1	1
Corn pickers acquired	1.8	1.4
Corn pickers, ending inventory	2.8	2.4
Acres in hay, high fert., oats for silage	0	28.0
Acres in corn, high fert., 1/5 for silage	0	240.0
Acres in corn, high fert., all picked	225.6	0
Total acres, picked corn	225.6	192.0
Profit, nearest dollar	$6270.00	$8047.00
Profit differential		+1777

As expected, the forage chopper has a marked effect on farm organization. With no chopper, all the corn must be picked. The limitation on October tractor services prevents more than 225.6 acres of corn from being harvested as ear corn. Consequently, 42.4 tillable acres on the farm must remain idle--an unprofitable alternative.[1] On the other hand, having the chopper available on the farm leads to a diversified organization which fully utilizes all available tillable acres. With the price restriction still holding for corn pickers, it becomes profitable to more fully utilize the chopper and reduce the investment in the corn pickers, so more hay and corn silage is produced relative to the amount of ear corn than was the case in all previous solutions.

These two solutions, again, provide a good example of the effect of predetermined resource fixity. With no chopper available to the farm, land was used to the point where its MVP dropped to zero. Were land not fixed in this particular problem, some would be sold--the amount sold stopping at the point where its MVP reaches salvage value. In this example, the value of land in use is less than its value in salvage. Since land has a positive slavage value, it is unrealistic to value it at zero.

The final factor of production to be set at a discrete level in the investment series are corn pickers. Table 4.5 shows the organization and profit for the two levels of investment.

Varying the amount of corn picker services available has less effect on organization than when the chopper was varied. The limitation of corn pickers in the first, 2 pickers, solution restricts the amount

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[1]In this case, the consequences of fixing the farm size at 320 acres, when 42.4 tillable acres remain idle, are plainly evident.

TABLE 4.5

PROFIT AND ORGANIZATION OF 320 ACRES, 4 TRACTORS, 1 CHOPPER AND 2 AND 3 CORN PICKERS

Description	Two Corn Pickers	Three Corn Pickers
Tillable acres	268	268
Tractors	4	4
Chopper	1	1
Corn pickers	2	3
Acres in hay, high fert., oats for silage	68	28
Acres in corn, high fert., 1/5 for silage	200	240
Acres in corn, high fert., all picked	0	0
Total acres, picked corn	160	192
Profit, nearest dollar	$7337	$7708
Profit differential		+$371

of corn which can be harvested by this method and as a consequence, more hay is produced. It is interesting to note that although the organization for the 3 picker solution is the same as for the previous solution with a chopper fixed, the investment in the additional corn picker reduces profit by $339.

The pattern of MVP's of the various resources throughout the investment series helps explain the effect of fixing resources arbitrarily at various levels. In the two land investment problems, when land was fixed at 320 acres, tillable acres had a value in use of $22.11, but for the 360 acre farm where land was more abundant, the MVP of tillable acres dropped to $10.28 which is $8.39 below salvage value. Because the other resources were combined with a greater amount of land on the 360 acre farm, their MVP's increased relative to those for the 320 acre organization.

The MVP of tillable acres decreases to $16.04 when the number of tractors is fixed at four, but increases to $34.78 when five tractors are available. Thus, it can be seen that in linear programming, as in other computational procedures, the MVP of one fixed resource increases as the amount of another resource is increased.

The value of the services from the forage chopper and the corn picker remains constant as tractors are varied from four to five. This is to be expected because in both cases, some of the chopper is sold and some corn pickers acquired. The value of the flow unit of the chopper is its salvage value and the MVP of the corn picker is equal to its annual acquisition cost. The MVP of tractor services for any given month, however, varies, depending upon the proportions of crops produced. A change in the proportions of crops changes the tractor requirements and thus their MVP.

The application of the model and the discrete investment rule to the original farm situation has resulted in a farm organization consisting of a 320 acre cash crop farm with 4 field tractors, 1 chore tractor, a forage chopper and 3 corn pickers. In addition, for the final farm organization, the remaining factors were fixed at the following levels: 2 plows, 2 discs, 1 drill, 2 corn planters, 2 cultivators and sprayers, 1 mower and rake, 5 wagons and 1 fertilizer spreader. Table 4.6 shows the complete change in farm inventory from the original organization to the final farm plan, including discrete investment levels for all assets.

TABLE 4.6

COMPLETE INVENTORY CHANGE
ORIGINAL ORGANIZATION TO FINAL FARM PLAN

Description	Original Inventory Amount	Original Inventory Value	Final Inventory Amount	Final Inventory Value[1]	Change In Value
Land, total acres[2]	160	$24,000	320	$60,000	$36,000
Machinery and Equipment					
Tractors	2	$2,400	4	$7,968	$5,568
Plows	1	100	2	321	221
Discs	1	150	2	467	317
Corn planters	1	180	2	382	202
Cultivators	1	75	2	329	254
Grain drills	1	350	1	296	-54
Mowers	1	180	1	142	-38
Rakes	1	220	1	162	-58
Choppers	1	1200	1	1,018	-182
Wagons	2	600	5	1,425	825
Fertilizer spreaders	1	220	1	195	-25
Corn pickers	1	700	3	3,292	2,592
Sprayers	1	100	2	364	264
Truck	1	620	1	558	-62
Silo filler	1	450	1	405	-45
Bulk tank	1	3,000	0	0	-3,000
Total		$10,545		$17,324	$6,779
Dairy Cattle					
Cows	32	$7,680	0	0	-$7,680
Yearling heifers	11	1,760	0	0	-1,760
Heifers calves	13	1,105	0	0	-1,105
Total		$10,545		0	-$10,545
Total farm investment		$45,090		$77,324	$32,234

[1]Original inventory value plus additional investment (price x number of units) minus depreciation on all units.

[2]Includes improvements.

The Final Farm Organization

The initial solution derived from the model is an optimum solution under the assumption of complete divisibility. Succeeding solutions derived from the investment series are not optimum in the strict sense. The 320 acre farm organization with other factors variable is optimum only in the sense that it is more profitable than the 360 acre alternative. (Of course, given the 320 acres, the remaining factors and products are optimum.) A major weakness of the rule for determining discrete investments is that the previously fixed resources may actually be fixed at the wrong level as more resource fixation occurs. That is, additional resource fixation may have a sufficient effect upon the MVP of previously fixed resources, that the excluded alternative, or even an alternative not tested, may lead to higher profits. If the MVP of land drops so low for the last solution that at least 40 acres could be sold before the MVP increased to the salvage value, it would indicate that given the resource fixation of succeeding solutions, too much land was acquired in the original investment solution.[1]

The change in acreage accounts for the greatest amount of change in inventory value. Although the additional acreage was priced at $250 per acre, the inventory value is $225, the net price the farmer would receive were he to sell it. For inventory purposes, the original land is valued at $150 per acre. Placing a value of $225 per acre on this land would have the effect of increasing the original net worth

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[1]Refer to pages 49-50 for such a solution.

of the farmer. Net worth, when the original farm is valued at the lower price is $36,000. Increasing the value of the land would increase net worth to $48,000. Either valuation will have no effect on the change in the value of inventory nor in the change in net worth.

TABLE 4.7

COMPARISON OF PROFIT:
OPTIMUM SOLUTION AND FINAL FARM PLAN

Description[1]	Optimum Solution	Final Farm Plan	Loss Involved in Obtaining Discrete Solution
Profit	$8,810	$6,796	$2,014
Labor income	6,912	4,828	2,084
Available for capital repayment	3,712	1,628	2,084
Needed for full capital repayment	3,635	2,548	--

[1]For a definition of the income categories, see page 37.

In Table 4.7, a comparison is made between comparable profit figures for the initial optimal solution and the solution derived from the investment series--the final farm plan. The third column in Table 4.7 shows the loss in profit due to fixing the assets at discrete levels.

In the final farm solution, labor income is $4828. In addition to this amount, the family also has available for consumption or investment (disposable income) the interest on owned assets and asset depreciation. Final asset value is $77,324 and the total debt is $59,242. Interest, at 6.5 percent, on the difference is $1175, and depreciation on the assets is $2729. However, half the depreciation

has already been added to cash (see page 16). The disposable income obtained by adding interest and half the depreciation to labor income is $7,367. These figures are summarized in Table 4.8.

TABLE 4.8

DISPOSABLE INCOME, FINAL FARM PLAN

Description	Amount
Labor income	$4,828
Interest on owned assets	1,175
One-half depreciation	1,364
Disposable income	$7,367

It remains to examine the capital accumulation side of the business. The difference between final total asset value and total debt is $18,082. This is the net worth of the farmer at the end of the year if none of the debt is retired. Should the family so choose, a maximum of $4,167 of the debt could be retired from disposable income if only the minimum $3,200 was used for family consumption. If this course of action were followed, net worth, at the end of the year would be $22,249. Therefore, depending upon the use of disposable income, net worth at the end of the year would be between $18,082 and $22,249.

CHAPTER V

SUMMARY AND CONCLUSIONS

Application of the Model

The model developed in this thesis actually is composed of two parts. The first part, which is the principal development of the thesis is the mathematical model dealing with the endogenous determination of fixed resources. The second deals with the discrete investment levels and is more a rule than a model. The range of application of the mathematical model is as wide as the use of linear programming for solving maximization and minimization problems involving resources which, in fact, are subject to variation. The modifications in the linear programming model made in this thesis would not be necessary nor especially useful where resources are rigidly fixed.

The model is particularly useful in a business which has resources as variable as does farming. It is capable of handling the very important resource allocation problems facing farmers today--such problems as diversification, specialization and vertical integration. An asset structure fixed at the initial levels and proportions, predetermines the outcome of an optimizing problem in a very real sense. The importance of scarce resources is unrealistically emphasized where the opportunity for further investment actually exists. A model with predetermined resource levels also has more of a tendency toward a more diversified solution than will this more general model. A model

in which resources are variable, is not forced to search for employment for factors of production having a very low or zero productivity. It is much more realistic to dispose of such resources which in turn will free funds for the expansion of the more productive enterprises. At the same time, this model does not overemphasize specialization which would be an equally undesirable result.

The alternative enterprises considered in the standard programming model are, by necessity, restricted by the group of resources considered fixed. In the more general model developed here, this is not the case. The entire initial set of assets can be disposed of and an entirely new type of business brought into being if such alternatives are specified in the model. However, the initial set of resources in this general model, does influence the outcome of the program. This is the case because the initial assets will not be sold so long as their value in use is greater than their salvage value. Therefore, their value in use, when combined with the other initial resources, or additional acquired resources, must have an MVP less than their salvage value before the initial resources would be exchanged for another set of resources--a new type of business being organized--or sold and the capital invested outside the organization.

It should not be inferred from the above statements that all the analysis problems of a firm have been solved with the conception of this model. The model still contains many of the problems organic to linear programming and as such has many of its shortcomings. An attempt

to alleviate one of these shortcomings resulted in the rule creating the discrete investment series described in the text.

The results obtained from any linear program are limited to the particular alternatives and activities included in the model. The determination of the combination of factors within each production activity is exogenous to the model itself and as such, must be dealt with independently. Erroneous factor combinations within the activities result in erroneous conclusions from the model.

In addition to the regular problems encountered in linear programming, this model is oversimplified and lacks realism concerning the budgeting and accounting techniques used. Depreciation and income (particularly dairy income) accruing through the year are not adequately handled nor are problems concerning the stock and flow characteristics of resources. The stock-flow problem is of major concern. The acquisition and salvage of resources involve units of stock such as tractors, buildings and machinery. The productivity of the stock, however, is measured in terms of the flow of services from that resource. As a result, the differential between acquisition and salvage values is, operationally, a function of the unit of service, and as a consequence, the buying and selling of resources, due to the nature of linear programming, is a function of the flow unit of the resource rather than of the unit of stock. This characteristic reduces the fixation restrictions for resources and thus creates a tendency toward more variability than actually exists. In the absence of a fully discrete programming model, where activities enter only in discrete units, the

infinite divisibility assumption of programming will continue to be a problem.

Further, the model is constructed under static economic assumptions. In the static framework, reference is not made to the management function nor to the interrelationships between the firm and household. The model assumes profit maximization as the only motivation for production. At the same time, enterprises which are distasteful or undesirable to the manager may simply be excluded as a possibility in the problem. The only management decisions beyond profit maximization considered in the model are the alternative enterprises acceptable to the manager, including minimum and maximum size restrictions.

The lack of risk and uncertainty considerations is another characteristic of the static economic assumptions under which the model is constructed. The input-output relationships are considered to be single valued. The effect of diminished crop yields or prices on the liquidity of the firm and status of the family are not taken into consideration. Its static nature precludes risk discounts and informal insurance schemes.

A major inconvenience of the model concerns the complex nature of it, which tends to create great size. To completely analyze a diversified farm organization, requires at best a large and unwieldly program matrix. Adding the complex of asset buying and selling activities and capital transfer activities as well as the specialized equations, compounds the size of the matrix involved. A complete programming

analysis including the features of this model, will invariably require the services of a large electronic computer, i.e. one with a large memory system.

The Empirical Results

The optimal solution to the model indicates that, under the conditions set forth in the problem, a cash crop farm is more profitable in the Central Michigan area than is a dairy farm even if the dairy utilizes the most labor efficient type of operation now in practice. It would be unwise to make recommendations from these results without further study, for several reasons. The crop yields considered in the application correspond to a very high degree of management skill--it would require a very good manager to obtain the results indicated by the most productive crop activities. Secondly, under exceptional management, milk yields may be greater than the maximum of 11,000 pounds considered in the model. An individual who was a very good dairy farmer, but lacked this ability in producing crops, may well find the profit situation reversed from the optimal solution.

The assumptions made, relative to labor, have an important effect on the outcome of the problem. The problem assumes off farm employment is available only a specified number of days every month for each of the two time periods. During the cropping season, this assumption makes it profitable to hire all necessary labor, so that the farmer's labor is fully employed throughout the period. Were monthly off farm labor employment available, it would have been profitable to accept off farm employment only during slack months, hiring labor only in excess of that supplied by the farmer during the rush seasons.

The fact that alternative employment is considered available off the farm during the winter months, has an influence upon the profitability of dairying. If the farmer's labor were not utilized off the farm during these months, the opportunity cost of dairying may be sufficiently great that this enterprise would enter the optimum solution.

The method of handling income from the dairy enterprise quite probably has an important influence on the outcome. If the monthly milk checks were reflected in the cash account, less cash would need to be borrowed outside the firm. Since cash in the initial optimum solution has a marginal value product of $7.42 per $100, the addition of the milk income to the cash account each month may have been sufficient to cause the dairy enterprise to enter the solution.

Price considerations should also be taken into account before making recommendations on the basis of the results of the program. While both the crops and the milk were conservatively priced, the relationship between the two has an important bearing on the outcome of the problem.

The optimum cropping program, itself, should receive special scrutiny. Since the initial assumptions were organized around a dairy farm, the possibilities of a larger variety of crops was not considered. This is perhaps, the most serious restriction of the results. In making the initial assumptions, the possibility of forming a cash crop farm

as a solution was desirable, but since the farm was a dairy farm, more emphasis was put on dairy organization than on the organization of a cash crop farm.

Further Study Indicated

The model as applied in this thesis, considers investment, organization and operation only for a one year period. Obviously, the optimum program the following year could not be a duplicate of the first year's solution. It would be highly desirable to incorporate the features of this model with the model developed by Loftsgard and Heady and referred to earlier in the introduction. Their model makes use of dated variables and arrives at an optimum solution through time, but does not consider the investment alternatives made possible by the incorporation of a model considering endogenously determined resource fixities. The combination of the two models should produce a much more realistic answer than either is able to product alone.

Further work is required on the stock-flow problem, which, as indicated previously, is not sufficiently handled by this model. Two problem areas exist with respect to this problem. One concerns the use of assets over time and the corresponding investment plan through time. The other concerns the effect on the fixity restrictions caused by imputing productivity values to flows rather than to stocks.

The application of linear programming to dynamic economics is worthy of further study. Price and resource mapping are examples of previous work in this area. The mapping technique, sometimes called

parametric programming, considers the effects of changes in prices and resources on farm organization. An important problem, which has as yet not been solved, is programming in terms of risk and uncertainty using distributed coefficients.

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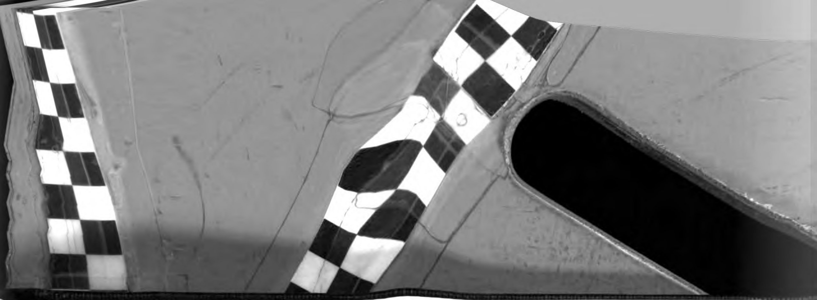

APPENDICES

APPENDIX A

Resource Fixity and Discrete Investment Levels
(Text reference: pp. 25-26)

First, consider the case of a resource which is acquired (positive investment). In the optimum solution, the MVP of the resource will equal its acquisition value. Assuming some fractional acquisition level in the optimum solution, the rule for obtaining discreteness will be applied.

For the discrete level in which the fraction is dropped (next lower discrete level), one would expect the MVP to be greater than in the optimal solution since a smaller amount of the resource is combined with at least as great an amount of the other resources. Immediately, then, the resource in question is no longer economically fixed (MVP > Ca). But at this lower discrete level, the second asset to be fixed in discrete units will, in all probability, itself be at a fractional amount. Fixing the second asset at a lower level will generally decrease the MVP of the first resource, and, conversely, fixing the second asset at the next higher level will further increase the MVP of the first asset considered. Thus, if all succeeding assets are fixed at the next higher discrete level, the MVP of the first will, in general, continue to increase, diverging more and more from its acquisition cost. At some point, it may become profitable to acquire an additional full unit of the first resource.

In the case when the first resource is initially fixed at the next higher discrete level, its MVP will decrease relative to that in the initial optimum solution. If, in the new solution, the MVP > Vs, there is no problem--the resource remains fixed. Should the MVP become less than the value of salvage and continue to decrease as more assets are fixed at discrete levels, it may become profitable, at some point, to salvage one full unit of the first resource.

The argument in favor of using this method to deal with indivisibility could be based on attaching equal probabilities to all values taken by the MVP of one resource as others are fixed at discrete levels. Given this assumption, the greater the differential between acquisition and salvage values, the greater the probability of the MVP of the resources fixed at discrete levels, falling between these values and the resource actually being economically fixed in the final solution.

It is quite evident, however, that the distribution of the values of the MVP of a resource when fixing other resources at discrete levels is not a uniform distribution. It seems much less likely that either of the extreme cases discussed above will occur than that some intermediate point will be reached. Thus, one would expect a distribution more like the normal distribution with a mean near or equal to the acquisition price. If the MVP values are normally distributed about the acquisition price, then it is equally likely that the final MVP will be greater than the acquisition price as below acquisition price. In this case, too, however, the greater the differential between

APPENDIX B

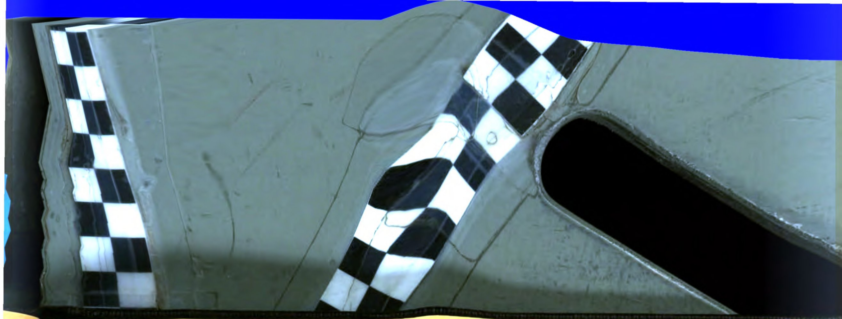

TABLE B.1

CROP ACTIVITY TITLES AND PROFIT COEFFICIENTS

Number	Description				Profit or C_j Coefficient Dollars
	Crop	Unit	% Cut for Silage	Fertilizer Level	
1	Corn	Acre	100	High	40.00
2	Corn	Acre	80	High	38.00
3	Corn	Acre	60	High	35.90
4	Corn	Acre	40	High	33.90
5	Corn	Acre	20	High	30.40
6	Corn	Acre	0	High	29.80
7	Corn	Acre	100	Medium	36.70
8	Corn	Acre	80	Medium	34.80
9	Corn	Acre	60	Medium	32.90
10	Corn	Acre	40	Medium	31.00
11	Corn	Acre	20	Medium	29.10
12	Corn	Acre	0	Medium	27.20
13	Corn	Acre	100	Low	34.60
14	Corn	Acre	80	Low	32.70
15	Corn	Acre	60	Low	30.80
16	Corn	Acre	40	Low	28.90
17	Corn	Acre	20	Low	27.00
18	Corn	Acre	0	Low	25.20
19	Hay	Acre	Oats only	High	32.20
20	Hay	Acre	Oats plus 3/20 hay	High	32.20
21	Hay	Acre	Oats plus 7/20 hay	High	32.20
22	Hay	Acre	Oats plus 11/20 hay	High	32.20
23	Hay	Acre	Oats plus 15/20 hay	High	32.20
24	Hay	Acre	Oats only	Medium	29.50
25	Hay	Acre	Oats plus 3/20 hay	Medium	29.50
26	Hay	Acre	Oats plus 7/20 hay	Medium	29.50
27	Hay	Acre	Oats plus 11/20 hay	Medium	29.50
28	Hay	Acre	Oats plus 15/20 hay	Medium	29.50
29	Hay	Acre	Oats only	Low	26.30
30	Hay	Acre	Oats plus 3/20 hay	Low	26.30
31	Hay	Acre	Oats plus 7/20 hay	Low	26.30
32	Hay	Acre	Oats plus 11/20 hay	Low	26.30
33	Hay	Acre	Oats plus 15/20 hay	Low	26.30

TABLE B.2

DAIRY ACTIVITY TITLES AND PROFIT COEFFICIENTS, PER COW

	Description				
Number	Ration No.	Parlor Type	Labor Efficiency Level	Silo Type	Profit or C_j Coefficient Dollars
34	1	Stanchion	Average	Upright	399.50
35	2	Stanchion	Average	Upright	379.50
36	3	Stanchion	Average	Upright	360.50
37	4	Stanchion	Average	Upright	399.50
38	5	Stanchion	Average	Upright	379.50
39	6	Stanchion	Average	Upright	360.50
40	7	Stanchion	Average	Upright	399.50
41	8	Stanchion	Average	Upright	379.50
42	9	Stanchion	Average	Upright	360.50
43	1	Stanchion	Efficient	Upright	399.50
44	2	Stanchion	Efficient	Upright	379.50
45	3	Stanchion	Efficient	Upright	360.50
46	4	Stanchion	Efficient	Upright	399.50
47	5	Stanchion	Efficient	Upright	379.50
48	6	Stanchion	Efficient	Upright	360.50
49	7	Stanchion	Efficient	Upright	399.50
50	8	Stanchion	Efficient	Upright	379.50
51	9	Stanchion	Efficient	Upright	360.50
52	1	Stanchion	Efficient	Bunker	399.50
53	2	Stanchion	Efficient	Bunker	379.50
54	3	Stanchion	Efficient	Bunker	360.50
55	4	Stanchion	Efficient	Bunker	399.50
56	5	Stanchion	Efficient	Bunker	379.50
57	6	Stanchion	Efficient	Bunker	360.50
58	7	Stanchion	Efficient	Bunker	399.50
59	8	Stanchion	Efficient	Bunker	379.50
60	9	Stanchion	Efficient	Bunker	360.50
61	1	Walkthrough	Average	Upright	399.50
62	2	Walkthrough	Average	Upright	379.50
63	3	Walkthrough	Average	Upright	360.50
64	4	Walkthrough	Average	Upright	399.50
65	5	Walkthrough	Average	Upright	379.50
66	6	Walkthrough	Average	Upright	360.50
67	7	Walkthrough	Average	Upright	399.50
68	8	Walkthrough	Average	Upright	379.50
69	9	Walkthrough	Average	Upright	360.50
70	1	Walkthrough	Efficient	Upright	399.50
71	2	Walkthrough	Efficient	Upright	379.50
72	3	Walkthrough	Efficient	Upright	360.50
73	4	Walkthrough	Efficient	Upright	399.50

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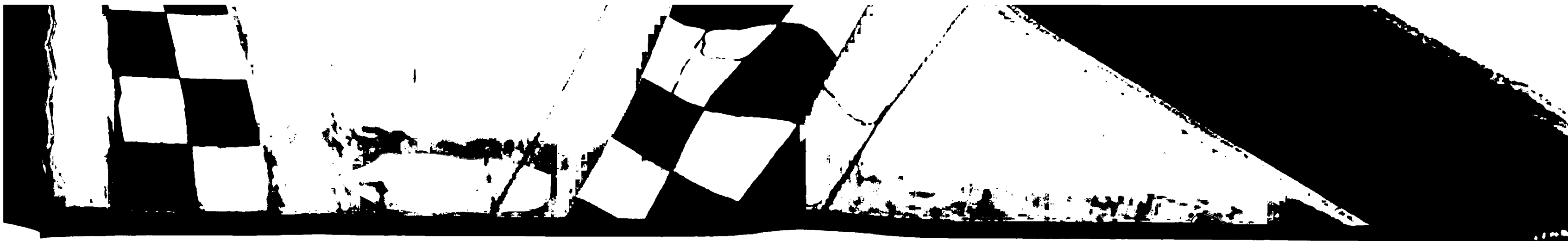

TABLE B.2--Continued

Number	Description				Profit or C_j Co-efficient Dollars
	Ration No.	Parlor Type	Labor Efficiency Level	Silo Type	
74	5	Walkthrough	Efficient	Upright	379.50
75	6	Walkthrough	Efficient	Upright	360.50
76	7	Walkthrough	Efficient	Upright	399.50
77	8	Walkthrough	Efficient	Upright	379.50
78	9	Walkthrough	Efficient	Upright	360.50
79	1	Walkthrough	Efficient	Bunker	399.50
80	2	Walkthrough	Efficient	Bunker	379.50
81	3	Walkthrough	Efficient	Bunker	360.50
82	4	Walkthrough	Efficient	Bunker	399.50
83	5	Walkthrough	Efficient	Bunker	379.50
84	6	Walkthrough	Efficient	Bunker	360.50
85	7	Walkthrough	Efficient	Bunker	399.50
86	8	Walkthrough	Efficient	Bunker	379.50
87	9	Walkthrough	Efficient	Bunker	360.50
88	1	Herringbone	Average	Upright	399.50
89	2	Herringbone	Average	Upright	379.50
90	3	Herringbone	Average	Upright	360.50
91	4	Herringbone	Average	Upright	399.50
92	5	Herringbone	Average	Upright	379.50
93	6	Herringbone	Average	Upright	360.50
94	7	Herringbone	Average	Upright	399.50
95	8	Herringbone	Average	Upright	379.50
96	9	Herringbone	Average	Upright	360.50
97	1	Herringbone	Efficient	Upright	399.50
98	2	Herringbone	Efficient	Upright	379.50
99	3	Herringbone	Efficient	Upright	360.50
100	4	Herringbone	Efficient	Upright	399.50
101	5	Herringbone	Efficient	Upright	379.50
102	6	Herringbone	Efficient	Upright	360.50
103	7	Herringbone	Efficient	Upright	399.50
104	8	Herringbone	Efficient	Upright	370.50
105	9	Herringbone	Efficient	Upright	360.50
106	1	Herringbone	Efficient	Bunker	399.50
107	2	Herringbone	Efficient	Bunker	379.50
108	3	Herringbone	Efficient	Bunker	360.50
109	4	Herringbone	Efficient	Bunker	399.50
110	5	Herringbone	Efficient	Bunker	379.50
111	6	Herringbone	Efficient	Bunker	360.50
112	7	Herringbone	Efficient	Bunker	399.50
113	8	Herringbone	Efficient	Bunker	379.50
114	9	Herringbone	Efficient	Bunker	360.50

TABLE B.3

ACQUISITION, CREDIT AND SALVAGE ACTIVITY TITLES AND PROFIT COEFFICIENTS

Number	Description	Profit or C_j Coefficients
115	Acquisition, Upright silo	284.82
116	Acquisition, Bunker silo	714.00
117	Acquisition, Herringbone parlor	1087.25
118	Acquisition, Walkthrough parlor	703.69
119	Acquisition, Automatic feed bunk	164.01
120	Acquisition, Tractor	356.70
121	Acquisition, Plow	18.63
122	Acquisition, Disc, drill	88.37
123	Acquisition, Disc, planter	48.22
124	Acquisition, Cultivator, sprayer	55.21
125	Acquisition, Chopper	279.31
126	Acquisition, Wagon	33.82
127	Acquisition, Mower, rake	98.81
128	Acquisition, Fertilizer spreader	26.10
129	Acquisition, Corn picker	156.31
130	Acquisition, Bulk tank	173.25
131	Acquisition, Loafing area, per cow	66.00
132	Acquisition, Cow and replacements	42.39
133	Acquisition, Non-auto silage feed bunk, per cow	8.12
134	Acquisition, Hay storage and feeding, per cow	33.00
135	Acquisition, Corn, 100 bushels	95.00
136	Acquisition, Hay, 10 tons	225.00
137	Acquisition, April labor, 260 hours	350.00
138	Acquisition, May labor, 260 hours	350.00
139	Acquisition, June labor, 260 hours	350.00
140	Acquisition, July labor, 260 hours	350.00
141	Acquisition, August labor, 260 hours	350.00
142	Acquisition, September labor, 260 hours	350.00
143	Acquisition, October labor, 260 hours	350.00
144	Acquisition, November to March labor, 1300 hours	1750.00
145	Land acquisition, cash and mortgage, 10 acres	12.50
146	Land acquisition, contract, 10 acres	12.50
147	Credit acquisition, land and mortgage, $100	5.50
148	Credit acquisition, 6% land contract, $100	6.00
149	Credit acquisition, 7% land contract, $100	7.00
150	Credit acquisition, land mortgage, $100	5.50
151	Credit acquisition, chattel mortgage, $100	6.50
152	Credit acquisition, silo dealer, $100	9.40

Continued

TABLE B.3--continued

Number	Description	Profit or C_j Coefficients
153	Credit acquisition, machinery dealer, $100	13.00
154	Salvage, tractor	356.70
155	Salvage, plow	18.63
156	Salvage, disc, drill	88.37
157	Salvage, disc, planter	48.22
158	Salvage, cultivator, sprayer	55.21
159	Salvage, chopper	279.31
160	Salvage, wagon	33.82
161	Salvage, mower, rake	98.81
162	Salvage, fertilizer spreader	26.10
163	Salvage, corn picker	156.31
164	Salvage, cow and replacements	42.39
165	Salvage, corn, 100 bushels	90.00
166	Salvage, hay, 10 tons	175.00
167	Salvage, land, 10 acres	12.50
168	Salvage, summer labor, 14 days	175.00
169	Salvage, winter labor, 10 days	125.00
170	Salvage, cash, $1000	40.00
171	Salvage, bulk tank	173.25
172	Credit repayment, $1000	55.00
173	Positive unit vector, sum equation, penalty	4444.00
174	Negative unit vector, sum equation	0.00
175[1]	Salvage hay equipment	

[1]All hay equipment was combined for the final computations. The set includes the disc and drill, mower and rake, and the fertilizer spreader.

TABLE B.4

INITIAL OPTIMUM SOLUTION

Activity No.	Organization and Imputed Values							
	Organization		Selected Imputed Values					
	Unit	Amount	Resource	Unit	MVP	Activity No.	Delta J
5	Acres	60.00	Disc, drill	AC[1]	$ 0.80	4	$ 3.26
6	Acres	227.20	May plow	1 hour	0.34	1	8.04
156	One each	1.00	Disc, planter	AC	0.67	12	9.80
161	One each	1.00	Cultivator, sprayer	do	0.62	7	12.52
159	One unit	0.83	Mower, rake	do	0.44	18	22.06
162	One unit	1.00	Fertilizer, spreader	do	0.16	13	19.76
164	One unit	32.00	Sept. chopper	do	3.52	19	1.88
171	One unit	1.00	Oct. tractor	1 hour	5.02	23	9.48
168	2 days/month	15.00	Oct. wagon	AC	1.42	24	11.28
169	100 hours	15.00	Corn picker	do	3.30	28	17.44
165	100 bushels	243.60	Corn	10 bu	9.00	29	21.94
166	10 tons	6.00	Hay	1 ton	17.50	33	26.48
138	260 hours	2.17	April labor	1 hour	0.72	34	5918.00
139	do	1.35	May labor	do	1.44	42	5950.00
142	do	0.26	June labor	do	1.44	43	3464.00
143	do	2.77	July labor	do	1.44	51	3494.00
129	One unit	2.38	Aug. labor	do	1.44	52	3484.00
120	do	3.00	Sept. labor	do	1.44	60	3506.00
123	do	1.06	Oct. labor	do	1.44	61	3978.00
126	do	4.77	N-M labor	100 hrs	134.28	69	4008.00
124	do	0.74	Herringbone capacity	do	30.08	70	2452.00
121	do	1.62	Auto bunk capacity	per cow	2.80	78	2482.00
146	10 acres	16.00	Cow, replacements	unit	52.00	79	2472.00
145	do	1.72	Cash 1	$100	7.42	87	2494.00
Unused cash	$100	0.00	5.5% credit	do	1.92	88	3590.00
Unused 5.5% credit	do	0.00	6% land contract	do	0.46	96	3620.00
Unused 6.5% credit	do	0.00	6.5% credit	do	0.92	97	2224.00
Unused 7% credit	do	360.00	Bulk tank capacity	gal	0.78	105	2254.00
			Land	T.A.[2]	20.72	106	2244.00
						114	2266.00
						117	0.00
						118	1144.00
						132	13.54

[1]Acres coverable. [2]Tillable acres.

TABLE B.5

OPTIMUM SOLUTION, 320 ACRES

	Organization and Imputed Values						
	Organization		Selected Imputed Values				
Activity No.	Unit	Amount	Resource	Unit	MVP	Activity No.	Delta J
5	Acres	60.00	Disc, drill	AC[1]	$ 0.79	4	$ 3.23
6	do	208.00	May plow	1 hour	0.00	1	7.96
156	One each	1.00	Disc, planter	AC	0.63	12	9.83
161	do	1.00	Cultivator, sprayer	do	0.58	7	12.66
159	One unit	0.83	Mower, rake	do	0.44	18	22.10
162	do	1.00	Fertilizer spreader	do	0.16	13	20.02
164	do	32.00	Sept. chopper	do	3.47	19	2.52
171	do	1.00	Oct. tractor	1 hour	4.76	23	9.63
168	2 days/month	15.00	Oct. wagon	AC	1.36	24	11.98
169	100 hours	15.00	Corn picker	do	3.13	28	17.74
165	100 bu	230.40	Corn	10 bu	9.00	29	22.71
166	10 tons	6.00	Hay	1 ton	17.50	33	26.95
138	260 hours	2.17	April labor	1 hour	1.43	34	5865.00
139	do	1.28	May labor	do	1.43	42	5896.00
142	do	0.26	June labor	do	1.43	43	3428.00
143	do	2.62	July labor	do	0.72	51	3459.00
129	One unit	2.20	Aug. labor	do	1.43	52	3428.00
120	do	2.67	Sept. labor	do	1.43	60	3459.00
123	do	0.96	Oct. labor	do	1.43	61	3941.00
126	do	4.40	N-M labor	100 hrs.	133.12	69	3972.00
124	do	0.65	HB capacity	do	0.00	70	2425.00
121	do	1.48	Auto bunk capacity	Per cow	0.00	78	2456.00
Unused cash	$100	0.00	Cow and replacement	Unit	51.44	79	2425.00
Unused 5.5% credit	do	0.00	Cash 1	$100	6.50	87	2456.00
Unused 6.5% credit	do	45.30	5.5% credit	do	1.00	88	3536.00
			6% land contract	do	0.00	96	3567.00
			6.5% credit	do	0.00	97	2186.00
			Bulk tank capacity	Gal.	0.73	105	2217.00
			Land	T.A.[2]	22.11	106	2186.00
						114	2217.00
						117	1673.46
						118	1090.80
						132	11.21

[1]Acres coverable. [2]Tillable acres.

TABLE B.10

PURCHASABLE ASSETS
PRICE, CREDIT TERMS AND DEPRECIATION

Asset Description	Price[1] Dollars	Down Payment Including Credit Fee Dollars	Balance Dollars	Credit Terms Years	Annual Payment $/$100	Annual Depreciation[2] Dollars
Tractor, 2-3 plow	3480	874	2610	3	42.51	348.00
Plow, 2 x 14"	257	68	193	3	do	18.00
Disc, drill	1153	292	865	3	do	84.50
Corn planter, disc, 2 row	613	157	460	3	do	46.69
Cultivator, sprayer, 2 row	625	160	469	3	do	53.65
Chopper, PTO, Silo filler	2725	685	2044	3	do	272.50
Wagon	330	86	248	3	do	33.00
Mower, side rake, 7'	1125	285	844	3	do	96.00
Fertilizer spreader, 10'	360	94	270	3	do	25.20
Corn picker, pull type, 1 row	1525	385	1143	3	do	152.50
Upright silo, 20'x60', complete	6669	3169	3500	3	39.76	284.82[3]
Bunker silo, 6x30x130, complete	5100	5100	--	-	--	714.00[3]
Bulk tank, 500 gal.	3300	829	2475	3	42.51	165.00
Double 3 Walkthrough, complete	6175	3775	2400	3	do	688.25[4]
Double 6 Herringbone, complete	9359	5527	3832	3	do	1063.85[4]
Loafing area for 10 cows	800	800	--	-	--	64.00[4]
Hay storage, feeding, 10 cows	400	400	--	-	--	32.00[4]
Feed bunk, non auto, 10 cows	50	50	--	-	--	8.00[4]
Feed bunk, auto, 10 cows	852	--	--	-	--	161.88[4]
Cow and replacements	332	332	--	-	--	41.56
Land, cash purchase, 10 acres	2500	2500	--	-	--	--
Land, mortgage, 10 acres	2500	1375	1125	20	8.40	--
Land, 6% contract, 10 acres	2500	250	2250	20	8.70	--
Land, 7% contract, 10 acres	2500	250	2250	20	9.40	--

[1]Prices were obtained from various dealers. Dealer prices were then increased uniformly by 10%.
[2]Depreciation rates from: Nielson, James M., Application of the Budget Method in Farm Planning, unpublished Ph. D. Thesis, Harvard University, Cambridge, Massachusetts, 1953.
[3]Includes repairs, taxes, insurance.
[4]Includes repairs.

TABLE B.11

COST OF MACHINERY REPAIR

Machine	Repairs as Percent of Machine Cost[1]
Tractor	7
Plow	5
Disc	4
Corn planter	3
Cultivator	3
Drill	3
Chopper	7
Wagons	5
Side rake	2
Fertilizer spreader	3
Corn picker	7
Sprayer	10
Mower	5
Silo filler	7

[1]Data from: Nielson, James M., op. cit.

TABLE B.12

FERTILIZER APPLICATION AND CROP YIELD ESTIMATES[1]

Item	Oat Silage	Hay	Hay Silage	Corn Grain	Corn Silage
Fertilizer (low)					
5-20-10	200 lbs			210 lbs.	210 lbs.
0-20-20		60 lbs	60 lbs.		
Yield	5.0 tons	2.5 tons	7.5 tons	60 bu.	10.6 tons
Fertilizer (med.)					
5-20-10	300 lbs			250	250
0-20-20		200 lbs.	200 lbs.		
Sidedress, N				40 lbs.	40 lbs.
Yield	8.0 tons	3.4 tons	10.2 tons	76 bu.	12.5 tons
Fertilizer (high)					
5-20-10	400 lbs			300 lbs	300 lbs
0-20-20		300 lbs	300 lbs		
Sidedress, N	30 lbs.			80 lbs	80 lbs
Yield	8.5 tons	4.2 tons	12.6 tons	90 bu.	15 tons

[1]Data modified from: Hoglund, C. R., and Cook, R. L., Higher Profits from: Fertilizer and Improved Practices, Agricultural Economics Mimeo 545, Michigan State University Agricultural Experiment Station and Soil Science Department, East Lansing, October, 1956. The high roles and yields are from unpublished data by the same authors.

TABLE B.13

TIME REQUIREMENTS FOR FIELD OPERATIONS[1]

Operation	Acres per Hour	Hours per Acre	Acres per 8 Hour Day
Plow	0.90	1.11	7.2
Disc	2.80	0.36	22.4
Drill	3.50	0.29	28.0
Plant corn	1.90	0.53	15.2
Cultivate	2.40	0.42	19.2
Spray weeds	2.50	0.40	20.0
Pick corn	0.75	1.33	6.0
Mow hay	2.0	0.50	16.0
Rake hay	1.9	0.53	15.2
Chop hay	1.1	0.91	8.8
Chop corn	0.8	1.25	6.4
Spread fertilizer	1.5	0.67	12.0

[1]Primarily from: American Society of Agricultural Engineers, Agricultural Engineers Yearbook, 2nd Edition, 1955, p. 89.

TABLE B.14

NUMBER OF FIELD WORKING DAYS PER MONTH[1]

Month	Days
April	12
May	15
June	18
July	20
August	21
September	17
October	15

[1]Data from unpublished sources.

TABLE B.15

DAIRY AND CROP CASH COSTS[1]

Item	Unit	Amount
Crops		
Fuel and oil	Per hour tractor time	$ 0.70
Alfalfa seed	Bushel	25.00
Oat seed	Bushel	1.45
Corn seed	Bushel	12.50
Fertilizer		
5-20-10	Ton	79.20
0-20-20	Ton	47.55
45-0-0	Ton	118.00
Weed spray	Per acre	3.00
Dairy		
Vet, breeding, elec., etc.	Per head	20.00
Milk for calves	Per head	4.00
Bedding	Per head	24.00

[1]Data from various unpublished sources.

TABLE B.16

DAIRY LABOR REQUIREMENTS[1]

Parlor Type	Level of Efficiency	Type of Silo	Minutes per Day per Cow[2]
Stanchion	average	Upright	17.76
Stanchion	efficient	Upright	10.56
Stanchion	efficient	Bunker	10.56
Walkthrough	average	Upright	12.06
Walkthrough	efficient	Upright	7.50
Walkthrough	efficient	Bunker	7.50
Herringbone	average	Upright	10.92
Herringbone	efficient	Upright	6.90
Herringbone	efficient	Bunker	6.90

[1]Primarily from: Hoglund, C. R., Boyd, J. S. and Snyder, W. W. "Herringbone and Other Milking Systems," Quarterly Bulletin, Michigan Agricultural Experiment Station, Michigan State University, East Lansing, Vol. 41, No. w (February, 1959) and Hoglund, C. R. and Wright, K. T., Reducing Dairy Costs on Michigan Farms, Michigan State University Agricultural Experiment Station Special Bulletin 376, East Lansing, May, 1952.

[2]Includes care of the entire herd.

TABLE B.17

RATIONS AND PRODUCTION FOR THE MILKING HERD, PER COW[1]

Ration Number	Silage Per Day Pounds	Silage Per Year Pounds	Silage TDN Pounds	Hay Per Day Pounds	Hay Per Year Pounds	Hay TDN Pounds	Corn Per Day Pounds	Corn Per Year Pounds	Corn TDN Pounds	Total TDN Pounds	Production Per Year Pounds
1	50	18,300	3,600	10	3,650	1,825	6.8	2,470	1,975	7,400	11,000
2	50	18,300	3,600	10	3,650	1,825	5.7	2,090	1,675	7,100	10,500
3	50	18,300	3,600	10	3,650	1,825	4.7	1,720	1,375	6,800	10,000
4	40	14,600	2,920	12	4,380	2,190	7.8	2,860	2,290	7,400	11,000
5	40	14,600	2,920	12	4,380	2,190	6.8	2,490	1,990	7,100	10,500
6	40	14,600	2,920	21	4,380	2,190	5.8	2,120	1,690	6,800	10,000
7	30	10,950	2,190	15	5,470	2,740	8.5	3,090	2,470	7,400	11,000
8	30	10,950	2,190	15	5,470	2,740	7.4	2,720	2,170	7,100	10,500
9	30	10,950	2,190	15	5,470	2,740	6.4	2,340	1,870	6,800	10,000

[1]Modified from: Jensen, Einar, et al., Input-Output Relationships in Milk Production, United States Department of Agriculture Technical Bulletin No. 815, Washington D. C., May, 1942.

TABLE B.18

RATIONS IN HAY EQUIVALENTS AND CORN EQUIVALENTS PER COW PER YEAR, INCLUDES REPLACEMENTS

Ration Number	Silage, Cows Tons	Silage, Cows Tons HE	Hay, Cows Tons HE	Silage, by Replacements Tons HE	Total Roughage Tons HE	Grain, Cows Bu CE	Grain, Replacement Bu CE	Total Grain Bu CE
1	9.15	3.05	1.82	2.00	6.87	44.1	13.3	57.4
2	9.15	3.05	1.82	2.00	6.87	37.4	13.3	50.7
3	9.15	3.05	1.82	2.00	6.87	30.7	13.3	44.0
4	7.30	2.43	2.19	2.00	6.62	51.1	13.3	64.4
5	7.30	2.43	2.19	2.00	6.62	44.5	13.3	57.8
6	7.30	2.43	2.19	2.00	6.62	37.9	13.3	51.2
7	5.47	1.82	2.74	2.00	6.56	55.2	13.3	68.5
8	5.47	1.82	2.74	2.00	6.56	48.6	13.3	61.9
9	5.47	1.82	2.74	2.00	6.56	41.8	13.3	55.1

TABLE B.19

AN EXAMPLE OF THE COMPUTATION OF MACHINE AND POWER RESTRICTIONS

1. April power restriction

   (a) Plowing is the most limiting restriction
   (b) One tractor can plow 7.2 acres per day
   (c) Twelve field working days in April
   (d) One tractor can plow a maximum of 86.6 acres in April.

2. April disc and drill restriction

   (a) One tractor can disc (2.8)(8) = 22.4 acres per day
   (b) One tractor can drill (3.5))8) = 28.0 acres per day
   (c) Set up a set of simultaneous equations where:

   x = number of days to disc
   y = number of days to drill

   We have $x + y = 12$
   $22.4x = 28.0\, y$

   (d) Solving,

   Disc 6.67 days
   Drill 5.33 days

   (e) Thus, one tractor can disc (6.67)(22.4) = 149 acres and one tractor can drill (5.33)(28.0) = 149 acres.