ECONOMIC ASPECTS OF FARM ORGANIZATION ON RED RIVER CLAY

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ABSTRACT

ECONOMIC ASPECTS OF FARM ORGANIZATION

ON RED RIVER CLAY

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In this thesis the problems of farm organization on a particular soil type in Manitoba were examined. Red River Clay was the soil type used in the study.

The case study approach was used in this thesis. One farm was chosen and the problems of farm organization and income maximization on this farm were studied. The empirical tool used in the analysis was linear programming. The farm chosen was considered typical of the area and the results of the study should be applicable to other farms in the area. The results show that the return realized by the farm business can be substantially increased through improved farm organization. The results also point out that in problems of farm organization the entire farm business must be considered and not just one segment or enterprise.

In this analysis it was discovered that the inclusion of rotations which produced no hay and which did not allow any of the livestock rotations considered in the study to be included resulted in a substantial loss of return. The choice of rotations among those which produced enough hay to

allow the cattle space to be fully utilized did not have much effect on the return.

The results show that farmers who fertilize at recommended rates should receive more return than those who use no fertilizer.

The choice of livestock enterprise to be included in the final plan also has an effect on the return realized. The livestock enterprise which results in the highest return is steer calves medium grain.

In the study it was found that gains in return could be made by increasing capital as long as capital was a limiting factor. With each increase in capital available the entire farm business must be reorganized.

In the study it was assumed that a hay market existed. If this hay market was lost the results of the study show that the farmer would have to make adjustments in his farm business. If he was unable to make these adjustments he would suffer a considerable loss in return.

If the price of the "key" enterprises rises sufficiently it will make necessary an adjustment of the farm business. This was tested by raising the price of cattle purchased for the cattle finishing enterprises. This decreases the net return of these enterprises. A five percent increase in this price causes no adjustment but a ten percent increase caused all cattle finishing enterprises to be removed from the final plan.

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CHAPTER I

INTRODUCTION

During recent years many changes have occured in the conditions which face Canadian agriculture. Many of these changes have adversely affected the position of agriculture.

One very important change is the change that has occured in the relationship of prices paid by farmers to those received by farmers. In 1951, the peak of a period considered favorable to agriculture, the index of prices received by farmers exceeded the index of prices paid by farmers by 84 points. During the period 1951 to 1959 this gap narrowed until in 1956 the index of prices paid by farmers exceeded the index of prices received. This condition also prevailed in 1957, 1958 and 1959. In 1959 the index of prices paid by farmers exceeded the index of prices received by 10 points.[1/] For both indices the base period was 1935 - 39. In this situation it is essential that the farmer organize his farm business in such a way that income is maximized.

In the same period another important change which

1/ Dominion Bureau of Statistics, Index Numbers of Farm Prices of Agricultural Products, Ottawa, Canada 1951 - 60. Dominion Bureau of Statistics, Price Index Numbers of Commodities and Services Used by Farmers, Ottawa, Canada 1951 - 60.

adversely affected the position of agriculture occured. The net farm income received by Canadian farm operators dropped from $1,933 million in 1951 to $1,108 million in 1959, a decrease of 43 percent.[2/]

Also in this period the capital investment rose approximately 16 percent from $9,458 million in 1951 to $10,925 million in 1959.[3/]

Farmers are thus faced with a cost price squeeze and a smaller total income from which they must receive their share and payment for an increasing capital investment. They are faced with a choice between two alternatives: (1) organizing the farm in such a way that an adequate farm income is realized or (2) leaving the farm.

Farm organization has become more complex in recent years. Farmers are confronted with an increasing number of alternate resources and enterprises from which they must choose their farm organization. This makes it very difficult for farmers to decide which combination of enterprises and resources is best suited to their particular situation.

2/ Dominion Bureau of Statistics, Research and Development Division, National Accounts Income and Expenditure, 1926-1956, Ottawa, Canada, 1958 Pg. 32.

3/ Dominion Bureau of Statistics, Agriculture Division, Quarterly Bulletin of Agricultural Statistics, January-March 1959 Pg. 23.

Mordecai Ezekiel sets out three alternative methods of changing farm organization, given resources, in order to increase income. These are:[4/]

1. Improved combination of enterprises with enterprise efficiency unchanged.

2. Present combination of enterprises left unchanged with improved enterprise efficiency.

3. Improved combination of enterprises with improved enterprise efficiency.

The production economist must guide farmers in the choice between these alternatives and in the choice of specific adjustments within each alternative.

Past studies in all parts of North America have shown how changes of the first type, improved combination of enterprises, can be used to increase farm income. Of particular interest to this study are the two studies done by J.C. Gilson of the University of Manitoba.[5/] Both these studies showed that income could be improved substantially through improved enterprise combination.

4/ Mordecai Ezekiel, "Most Advantageous Organization and Practices in an Area", Social Science Research Council, Research in Farm Management, Scope and Method, New York, 1932.

5/ Gilson J.C., An Application of Linear Programming to Farm Planning, Faculty of Agriculture and Home Economics, University of Manitoba, Winnipeg, Manitoba, March, 1960. Gilson J.C., Economic Aspects of Alternative Crop Rotations and Beef Production Systems, Faculty of Agriculture and Home Economics, University of Manitoba, Winnipeg, Manitoba, May, 1960.

I. SCOPE AND OBJECTIVES

The central objective of this thesis was to study the problem of improving farm organization on a particular soil type of Manitoba - Red River Clay.

The specific objectives given below outline the particular aspects of farm organization that were studied.

Specific Objectives

1. An attempt was made in the study to determine how much grass and legume production should be carried out on Red River Clay soils. It was hypothesized that the amount of grass and legume production has a substantial effect on the income level received. Agronomists have set up certain minimum levels of grass and forage production necessary for soil conservation. In this study it is to be determined whether or not production above this level can increase income.

2. The second objective is to determine whether or not the recommendations made by agronomists for fertilizer use on Red River Clay can be defended economically. It is hypothesized that a higher net income can be realized by farmers who fertilize at the recommended rates than by those who use no fertilizer.

3. In the study an attempt will be made to determine which type of beef cattle production is best suited to Red

River Clay. There are two major types of beef cattle production: (1) cattle finishing enterprises in which cattle are purchased and fattened for slaughter, and (2) cow - finished calf enterprises in which the calves are raised from birth to slaughter. Within each of these two classes there are several sub-divisions. It is hypothesized that the income received by the farm business will depend a great deal on the specific beef cattle enterprise chosen.

4. The fourth objective is to determine what the effect of varying the level of "key" resources will be. It is hypothesized that the quantity of these "key" resources available will have an effect not only on the income level received but also on the type of production plan which is most profitable.

5. The last objective is to determine the effect of price changes in "key" enterprises. It is hypothesized that these price changes will effect not only the income level but also the nature of the most profitable plan.

The scope of this study has been outlined implicitly in the discussion of the objectives. It will be useful to point out why Red River Clay soil was chosen as the soil type to be studied. Red River Clay is one of the more productive soils of Manitoba and thus also one of the more expensive. Many farmers on this soil type are not receiving the maximum possible farm income. As pointed out before studies done on this soil type by J. C. Gilson show that

farm income can be increased through improved farm organization. In addition a great deal of work has been done by agronomists on Red River Clay soils. As a result there is more data available on yields, fertilizer responses and possible rotations than for other soil types of Manitoba.

II METHOD

Since this study involves farm organization, linear programming is the empirical tool which will be used. Linear programming is a tool which allows the selection of optimum production plans given assumptions about enterprises to be considered and resources available. This is exactly what will be attempted in the study and thus linear programming is well suited for use in this study. The results that are determined are completely applicable only to the farm that is used in the study. The results can however be used on farms which closely resemble the farm used in enterprises considered and resources available.

CHAPTER II

THEORETICAL BACKGROUND

I. LINEAR PROGRAMMING AND THE BUDGET APPROACH

Linear programming and the comparative budget approach, which has been used in agricultural economics for many years, have much in common. A budget is a detailed production plan for a firm for some future period. Every firm has at its disposal a certain complement of resources which may be used in the production plan. These resources are fixed in that it is assumed that the amount available cannot be increased during the period under discussion. Variable resources will also be used in the production plan but the quantity available can be increased to any required amount during the period under discussion. Finally there is present a certain number of enterprises, any of which could be carried out using only those types of fixed resources available.

A production plan for a future period consisting of a combination of these given enterprizes which uses no more of the fixed resources than are available is called a budget. A budget or production plan might consist of only one enterprise or a number of enterprises. The budget might use the entire quantity available of one resource and none of

another or it might use the total amount of each resource available. It can be seen that there will be for any firm a number of possible production plans or budgets.

Using the comparative budget approach a number of possible production plans or budgets are drawn up and for each plan the receipts, expenses and thus the profits are calculated. Then the production plan or budget which yields the most profit is chosen as the one which should be used by the firm.

One disadvantage of the comparative budget approach is that as the number of fixed resources and enterprises considered increases, the number of possible budgets increases more than proportionately. The research worker soon finds that it is impossible to consider all possible budgets. It is then necessary to decide which production plans, of all those possible, should be considered. This can only be decided by the subjective judgement of the research worker. If this is the case there always remains the possibility that there is a production plan that has not been considered that is superior to all those that have been considered.

Linear programming is a systematic, mathematical technique which is used to find exactly the same results as are determined using the budget approach. In linear programming the same fixed resources and the same enterprises that were used in the budget approach are again utilized.

Using linear programming the number of possible production plans is not limited as it is in the budget approach. The technique allows all possible enterprise combinations to be considered simultaneously. It thus assures that the plan which returns the maximum profit is the plan selected.

The use of linear programming also reduces the amount of computation involved. This can be even further reduced through the use of the electronic computer. The electronic computer can be used for linear programming but not for the ordinary budget approach.

II. HISTORICAL DEVELOPMENT OF LINEAR PROGRAMMING

Linear programming was first developed in 1947 for the solution of managerial problems confronting the United States Air Force.[1/] It was used on such problems as that of determining how a maximum amount of goods could be transported with a limited number of pilots, aircraft and air fields. Economists soon became interested in the adoption of linear programming to economic problems.[2/] The first application of linear programming to the problems of agricultural economics

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1/ Robert Dorfman, Application of Linear Programming to the Theory of the Firm (Berkley and Los Angeles, The University of California Press, 1951), Pg. 4.

2/ Ibid., Pg. 5.

consisted of the selection of the most profitable crop rotation.[3] In 1951 linear programming was first used to find a minimum cost livestock ration that also satisfied certain minimum nutrient levels.[4] In 1954 the technique was used to select optimum combinations of livestock enterprises.[5] Finally in 1955 linear programming was used to select the complete optimum farm plan including both livestock enterprises and crop rotations.[6] In the study being discussed here linear programming will be used to select a complete farm plan.

Developments in the technique also allow optimum plans to be selected at various levels of a resource restriction. In this case the optimum plan selected at one quantity level of the resource and then a new optimum plan is selected at another quantity level.[7] Techniques have also been developed

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[3] Clifford Hildreth and Stanley Reiter, "On the Choice of a Crop Rotation Plan", in T.C. Koopmans, editor, Activity Analysis of Production and Allocation (New York, John Wiley and Sons Inc., 1951), Pg. 177 ff.

[4] Fredrick Waugh, "The Minimum Cost Dairy Feed", Journal of Farm Economics August, 1951, Pg. 281 ff.

[5] E.R. Swanson, and K. Fox, "The Selection of Livestock Enterprizes by Activity Analysis", Journal of Farm Economics February, 1954, Pg. 78 ff.

[6] G.A. Peterson, "Selection of Maximum Profit Combination of Livestock Enterprises and Crop Rotations", Journal of Farm Economics August, 1955, Pg. 546 ff.

[7] E.O. Heady and W. Candler, Linear Programming Methods (Ames, Iowa State College Press, 1958), Pg. 232 ff.

which allow the optimum to be selected for different price levels.[8] Both these techniques will be used in the present study.

III. BASIC CONCEPTS OF LINEAR PROGRAMMING

There are three concepts which are basic to an understanding of linear programming and for which definitions must be given - resources, products and production processes.

Resource

Dorfman defines a resource as :[9]

> We may think of all the physical and intangible things used by the firm as being grouped into classes in such a way that it is a matter of indifference to the firm or any firm which member of a class it obtains for use in its productive work, such a class we shall call a resource, a factor or an input.

A brief example should help to clarify this concept. Labour is often considered by laymen and in some work by economists to be one resource. In agriculture, labour available at different seasons of the year is not identical. It is not a matter of indifference to a farmer whether he receives an additional hundred hours either in January or

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[8] Ibid., Pg. 265 ff.

[9] Robert Dorfman, Application of Linear Programming to the Theory of the Firm (Berkley and Los Angeles, The University of California Press, 1951), Pg. 13.

August, therefore labour must be classified into groups in such a way that as far as the farmer is concerned one hour of labour in a particular group is identical with any other member.

Product

A product is defined in exactly the same way as a resource except that the products rather than being used in productive effort are the result of productive effort. Products are also classified into groups such that the individual or firm desiring a member is indifferent as to which member is received.[10/]

Productive Process:

Dorfman defines productive process as a "physical event or series of events in which men participate purposefully in order to transform some resources into products".[11/] Two processes are classified as two instances of the same process if they use the same resources in the same proportions and produce the same products in the same proportions.

To clarify this definition Dorfman expresses the relationship mathematically borrowing a notational

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10/ Ibid., Pg. 13.

11/ Ibid., Pg. 14.

procedure from chemistry:[12/]

$$E_i: a_{i1}F_1 + a_{i2}F_2 + \cdots + a_{im}F_m \longrightarrow b_{i1}C_1 + b_{i2}C_2 + \cdots + b_{in}C_n.$$

Where E_i is a productive process, using m resources and producing n products. $F_1, F_2, \ldots, F_m$ represent unit levels of these resources and $C_1, C_2, \ldots, C_n$ unit levels of the products, $a_{i1}, a_{i2}, \ldots, a_{im}$ represent the quantities of each of the factors used by the process E_i, while $b_{i1}, b_{i2}, \ldots, b_{in}$ represent the quantities of each of the outputs produced by E_i.

A second productive process using the same m resources and producing the same n outputs could be represented:

$$E_j: a_{j1}F_1 + a_{j2}F_2 + \cdots + a_{jm}F_m \longrightarrow b_{j1}C_1 + b_{j2}C_2 + \cdots + b_{jn}C_n.$$

Then if:

$$\frac{a_{i1}}{a_{j1}} = \frac{a_{i2}}{a_{j2}} = \cdots = \frac{a_{im}}{a_{jm}} = \frac{b_{i1}}{b_{j1}} = \frac{b_{i2}}{b_{j2}} = \cdots = \frac{b_{in}}{b_{jn}}$$

the two processes E_i and E_j are two instances of the same process.

To further clarify this concept suppose that there are two fluid milk enterprises using exactly the same resources except that in one enterprise the cows are fed a high grain - low forage ration and in the other the cows are fed a low grain - high forage ration.

[12/] Ibid., Pg. 14.

Then: E_1: AF_1 + 10,000 H + 3,200 G $\longrightarrow$ 11,000M

and E_2: AF_1 + 15,000 H + 2,500 G $\longrightarrow$ 10,500M

Where E_1 is the enterprise using the low forage - high grain ration and E_2 is the enterprise using the high forage - low grain ration. In both expressions A represents the amount of all the other resources used. The unit level of these resources is represented by F_1. H represents the unit level of forage, G the unit level of grain and M the unit level of milk production.

Ignoring the other resources, process E_1 uses 10,000 pounds of forage, 3,200 pounds of grain and produces 11,000 pounds of milk. Process E_2 uses 15,000 pounds of forage, 2,500 pounds of grain and produces 10,500 pounds of milk. Commonly these enterprises might be considered identical but since they do not use the resources in the same proportion and do not produce the output in the same proportion they are not instances of the same process. That is :

$$\frac{A}{A} \neq \frac{10,000}{15,000} \neq \frac{3,200}{2,500} \neq \frac{11,000}{10,500}$$

Now that these three fundamental definitions have been set up the assumptions on which linear programming is based can be presented.

IV. ASSUMPTIONS

Dorfman sets out three assumptions:[13/]

> 1. The productive opportunities of an economy or economic unit are defined by the resources and the productive processes available to it. The quantities of at least some of these resources are finite and so is the number of productive processes available.
>
> 2. Any productive process may be used at any positive level consistent with the supply of resources and the output of products is proportional to the level at which the process is used.
>
> 3. Several productive processes may be used simultaneously if the resource supply is adequate. If this is done, the consumption of each resource is the sum of the consumption of the individual processes used, and the output of the products is the sum of the outputs of the individual processes.

The first assumption was used in the discussion of the budget approach. It implies that the quantity available of some of the resources, but not necessarily the quantity of all the resources, cannot be increased during the time period under consideration. These are the fixed resources. Variable resources are available in unlimited quantity to the firm. This is the situation usually encountered by a firm. A farm, for example, has at its disposal fixed quantities of such resources as land, buildings and machinery. To these fixed resources, variable resources such as

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13/ Ibid., Pg. 18.

fertilizer, gasoline and feed can be added in unlimited quantities.

The assumption also sets out the condition that the firm is faced with a finite number of possible production processes. This again is the usual situation facing the firm. The nature of the fixed resources, the individual preferences of the entrepreneur and other factors all serve to limit the number of possible production processes.

The second assumption sets out the divisibility of both the products and the resources. Since a process is allowed to enter at any positive level it follows that it can enter at a level that is not a whole number. For example, the farm plan might include 20.68 head of cattle. Since the processes are divisible it follows that the resources used must also be divisible. The word "positive" is introduced into the assumption to serve as a check on the mathematics of the technique. Although complete divisibility is not an entirely valid assumption the solutions determined are not usually seriously affected by moving to the nearest physically possible level.

In the second part of the assumption the linear relationships of the technique are set out. If 2 units of factor X_1 and 3 units of factor X_2 are required to produce 1 unit of output Y, then 4 units of X_1 and 6 units of X_2 will be required to produce 2 units of Y. This assumption is not valid in many instances as "increasing" or "decreasing"

returns rather than "constant" returns to scale occur. Linear programming can be set up to handle these situations.

To do this it must be remembered that one process is different from another if it uses factors or produces output in different proportions. To incorporate the decreasing returns a series of processes are set up each of which uses more input per unit of output than the last. Suppose that three processes are set up using the resource X to produce Y. The first process is assumed to use 1.0X for every Y produced, the second 1.1X for every Y produced, and the third, 1.2X for every Y. Next the "relevant range" for each process must be determined. Suppose that for the first 50 units of Y the actual relationship between factor and product is closely approximated by the relationship expressed by process 1. Also suppose that the relationship between factor and product for production from 50 to 75 is approximated by process 2 and the relationship for output between 75 and 90 approximated by process 3. The program is set up so that any production under 50 units is carried out by process 1, any output over the 50 units but below 75 by process 2 and any output above 75 but below 90 by process 3. This shows only how decreasing returns may be handled but increasing returns can be handled in exactly the same manner. The nature of the actual factor - product relationship will determine the number of processes used and the intervals chosen.

The third assumption sets out the condition that the

results of any process are the same whether that process is carried out alone or in combination with one or more other processes. It is assumed that no complementary relationships exist. Many examples which invalidate this assumption can be cited. One example that is often used is the complementary relationship between forage and grain production. Suppose that there is a given plot of land, half of which is devoted to continuous forage production and half of which is devoted to continuous grain production. The total yield over a two year period will change if the production pattern is changed so that in one year the entire plot is devoted to forage and in the second year only grain is grown. The two processes are thus not additive.

To handle this type of situation in linear programming the processes which are complementary are combined to make one process. In the example given above a process is set up for each combination of forage and grain that is to be studied. Thus a unit process of one acre consisting of one-tenth of an acre of grass and nine-tenths of an acre of grain is set up, another process containing two-tenths of an acre of forage and eight-tenths of an acre of grain and so on.

The inputs required and outputs which result from each of these processes can then be determined. Each process reflects the complementary relationship that would be found with that particular combination of the two enterprises.

There is one further assumption which is not explicitly

set out by Dorfman but has been set out by Heady and Candler.[14] The technique of linear programming assumes single valued expectations for input - output coefficients and for prices. Although this assumption is not completely valid in agriculture, it has been defended by Heady and Candler on the grounds that it has been used in many other types of agricultural economics research including budgeting.

V. DEFINITION OF LINEAR PROGRAMMING

Now that the framework within which linear programming operates has been set up a formal definition can be presented. The definition used by Dorfman is as follows:[15]

> Linear programming has been defined to be the maximization or minimumization of a mathematical function subject to certain linear inequalities.

The mathematical presentation of this definition will help to clarify the approach used in linear programming.[16] It is first necessary to set up the linear inequalities which limit the maximization of the linear function. As pointed out earlier in both the budget approach and the linear programming approach the firm is faced with a finite

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[14] E.O. Heady and W. Candler, Linear Programming Methods (Ames, Iowa State College Press, 1958), Pg. 18.

[15] Robert Dorfman, Application of Linear Programming to the Theory of the Firm (Berkley and Los Angeles, The University of California Press, 1951), Pg. 12.

[16] Ibid., Pg. 19 ff.

number of possible enterprises and a finite quantity of a number of resources. Each enterprise included uses a certain amount of each resource, the amount depending on the level at which the enterprise is included in the plan. The amount of a given resource, used by any plan can be represented:

$$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots + a_{mn}x_n = A_m$$

In this expression A_m represents the total quantity of resource m used. x_1, x_2, x_3, ... x_n represent the levels at which enterprises 1, 2, 3, ... n are included in the plan. The amount of resource m required by one unit of enterprise 1 is represented by a_{m1}, the amount of resource m required by enterprise 2 by a_{m2}. The other "a" terms are similarly interpreted. The expression can be read: the summation of the amounts of resource m used by each enterprise equals A_m.

If there are k fixed resources we can develop a system of equations each of which represents the total amount of one resource used. The resulting system is:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots + a_{1n}x_n = A_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots + a_{2n}x_n = A_2$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \ldots + a_{3n}x_n = A_3$$
$$\text{---------------------------------------}$$
$$a_{k1}x_1 + a_{k2}x_2 + a_{k3}x_3 + \ldots + a_{kn}x_n = A_k$$

The firm has at its disposal quantities of each of these resources. These can be represented by S_1, S_2, ..., S_k. In order for the production plan to be feasible it is necessary that :

$$A_1 \leqslant S_1$$
$$A_2 \leqslant S_2$$
$$A_3 \leqslant S_3$$
$$\vdots$$
$$A_k \leqslant S_k$$

This then is the system of linear inequalities which form the framework within which the linear function must be maximized.

In economics work the linear function considered is usually the profit function, to be maximized, or the cost function, to be minimized. In this study the profit function is being considered. For each of the possible enterprises (1, 2, ..., n) a net price is calculated. The usual procedure for calculation of this net price is to subtract from the gross price, the variable expenses. This net price is then the return to the fixed factors.

The profit function can be written:

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots + c_nx_n$$

Where $x_1, x_2, x_3, \ldots, x_n$ represent the amount of enterprises 1, 2, 3, ..., n included in the production plan and $c_1, c_2, c_3, \ldots, c_n$ represent the net price of unit outputs of the enterprises. Z is the net return of the production plan which includes the enterprises at the given levels.

Using linear programming the production plan which maximizes the value of Z and at the same time satisfies the system of inequalities is determined.

VI. MARGINAL CONDITIONS FOR EQUILIBRIUM OF THE FIRM

Marginal analysts have long been concerned with the determination of the point of equilibrium of the firm. As a result the conditions for this equilibrium are well developed. Hicks summarizes them as follows:[17/]

> 1. Corresponding to the condition price = marginal cost, we have three sorts of conditions:
> a) The price ratio between any two products must equal the marginal rate of substitution between the two products (this is now a technical rate of substitution).
> b) The price ratio between any two factors must equal their marginal rate of substitution.
> c) The price ratio between any factor and any product must equal the marginal rate of transformation between the factor and the product (that is to say, the marginal product of the factor in terms of this particular product).
>
> 2. Next there are the stability conditions. For the transformation of a factor into a product we shall have the condition . . . of diminishing marginal rate of transformation or diminishing marginal product. For the substitution of the one product for another we shall have a condition of 'increasing marginal rate of substitution', that is to say, increasing marginal cost in terms of the other product (marginal opportunity cost). For the substitution of one factor for another, 'diminishing rate of substitution'.

17/ J.R. Hicks, Value and Capital (London, Oxford University Press, 1957), Pg. 86 - 87.

These conditions will not be discussed further here but the next section will show that linear programming also satisfies these conditions.[18/]

VII. LINEAR PROGRAMMING AND THE SATISFACTION OF THE MARGINAL CONDITIONS FOR THE EQUILIBRIUM OF THE FIRM

Product - Product Principle

This principle is concerned with the determination of the combination of enterprises which will maximize returns. If a given amount of any resource is available, there is for each enterprise a maximum amount of that enterprise which can be produced with the given amount of that resource. If two enterprises (Y_1 and Y_2) are singled out it can be assumed that a maximum of 100 units of Y_1 can be produced with a given quantity of a factor (X_1) or 50 units of Y_2 with the same quantity of X_1. This is illustrated in Figure 1.

Since linear relationships are assumed in linear programming the straight line connecting the maximum output of Y_1 and the maximum output of Y_2 represents all physically possible outputs of Y_1 and Y_2 given the fixed quantity of X_1. This line is the iso - resource curve for factor X_1.

[18/] For further discussion of the marginal conditions see Ibid., Pgs. 78 - 98.

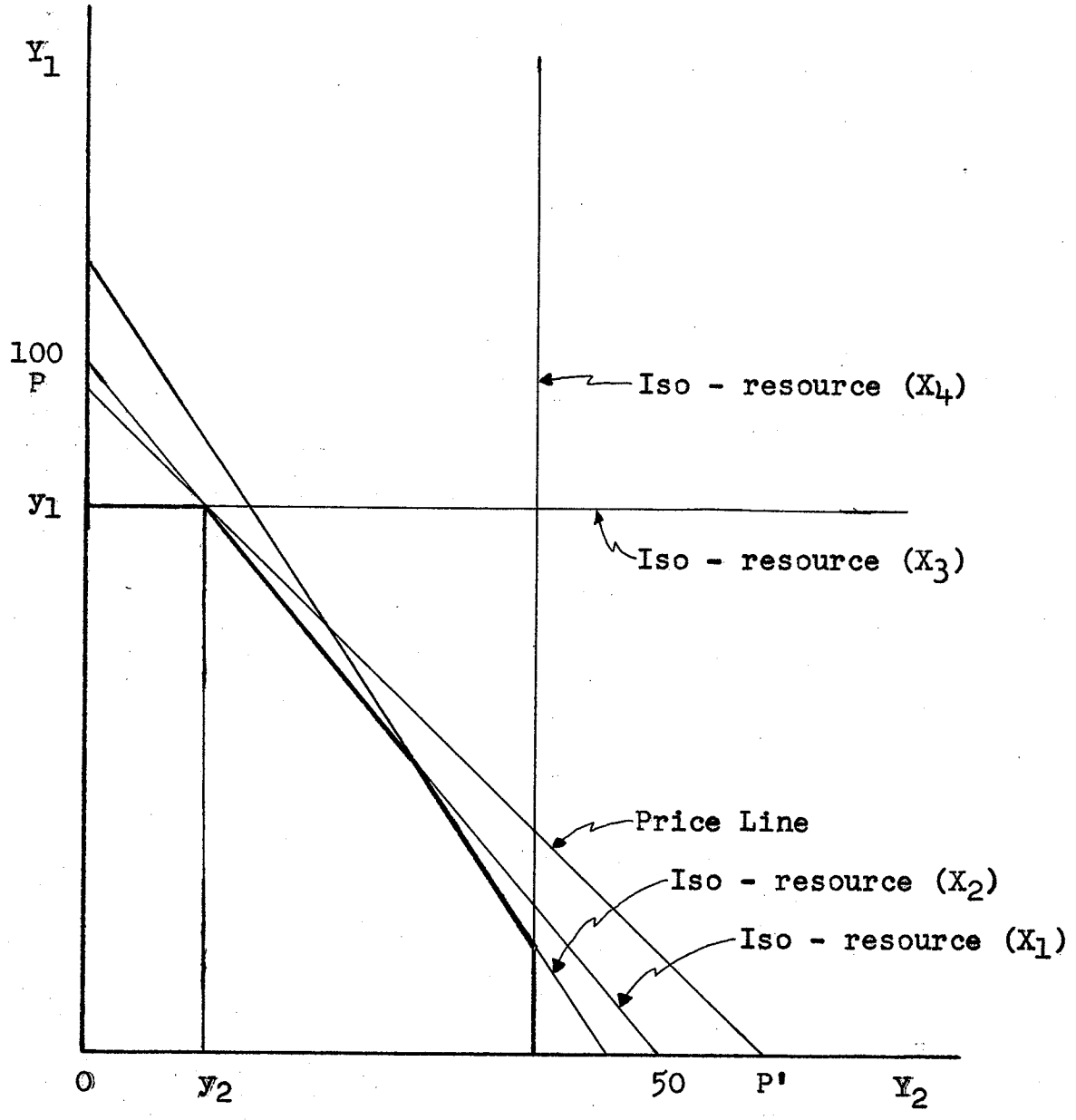

FIGURE 1

PRODUCT - PRODUCT PRINCIPLE

Similarily iso - resource curves can be developed for all other fixed factors. Suppose that there are four fixed factors X_1, X_2, X_3, and X_4. The iso - resource curves for each of these are illustrated in Figure 1.

If all factors are considered simultaneously it can be seen that any combination of Y_1 and Y_2 found to the right of the heavy line in Figure 1 is physically impossible. That is it will use more of at least one resource than is available. This heavy line is then the composite iso - resource curve.

For the satisfaction of the product - product condition the price line must be introduced. In Figure 1 the price line is represented by the line PP'. For the satisfaction of the product - product principle output should occur where the price line is tangent to the iso - resource curve. This occurs in Figure 1 where output of Y_1 is equal to Oy_1 and the output of Y_2 is equal to Oy_2.

It can be seen that the price line PP' can be rotated to a considerable degree in either direction before the point of tangency shifts. This is how the satisfaction of this condition (and the other marginal conditions) by linear programming differs from the satisfaction by the usual marginal analysis. In marginal analysis even a minute rotation of the price line causes a shift in the point of tangency and thus changes the optimum combination. Linear programming is said to maximize in the large.

Factor - Factor Principle

In order to understand the satisfaction of this condition by linear programming it is first necessary to develop the concept of a process ray. If there is a process which uses only two resources, from the assumptions, output can only be increased by increasing the amounts of these resources proportionately. Also as the amount of these resources is increased the output also increases proportionately. These relationships can be illustrated graphically by a straight line such as the line numbered 1 in Figure 2. This line is called a process ray.

For the production of any output there will probably be two or more processes each using exactly the same resources but in different proportions. Each of these processes can be represented by a process ray. In Figure 2 four such process rays are illustrated.

To develop an iso - product curve it is necessary to determine a point on each ray which represents a given output. This is done in Figure 2 and the points connected to form an iso - product curve.

For the satisfaction of the principle it is again necessary to introduce a price line - represented by AB in Figure 2. Given this price line the optimum combination of factors is found where Ox_1 of factor X_1 and Ox_2 of factor X_2 are used. Again the price line can be rotated considerably before the optimum position changes.

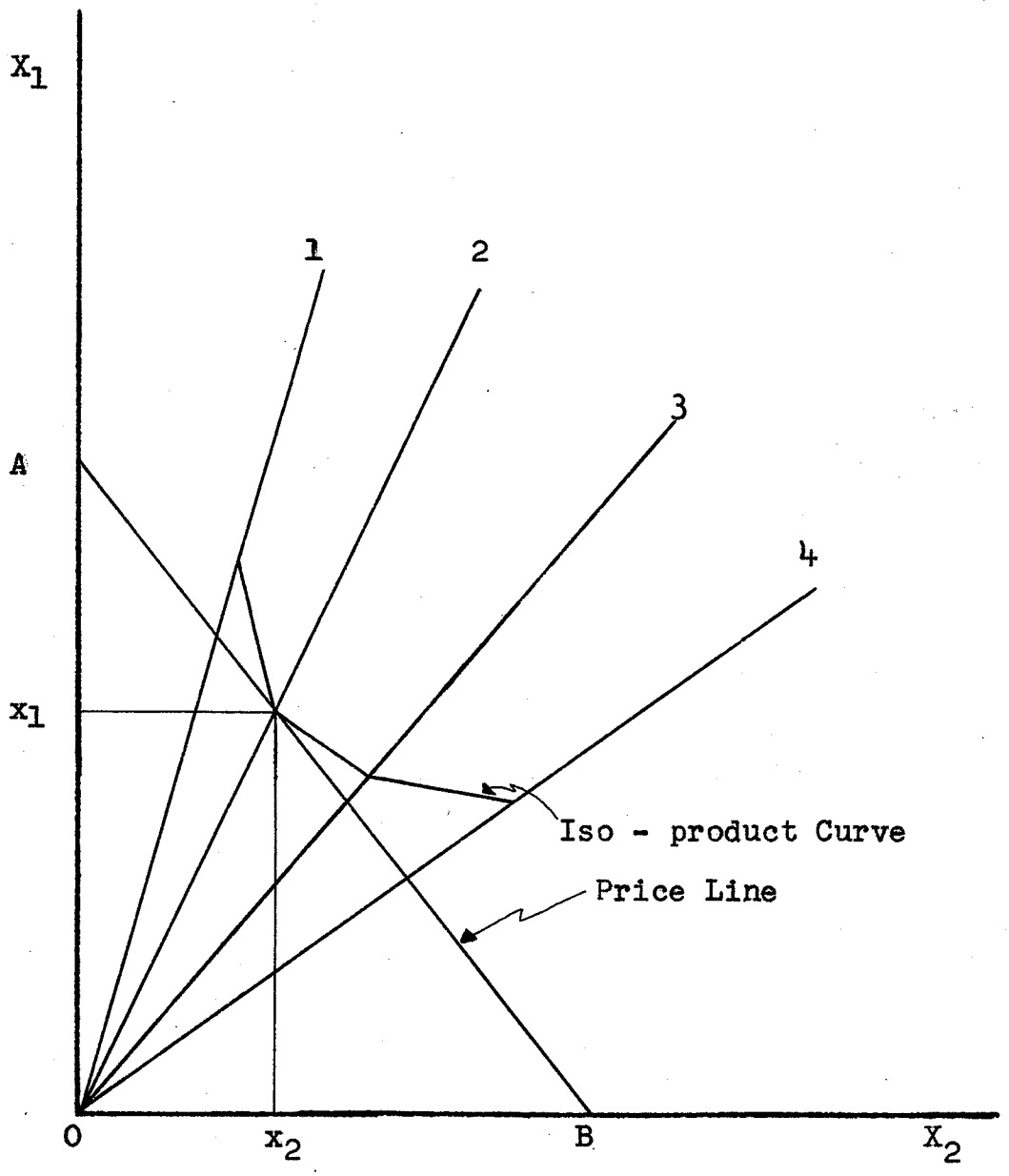

FIGURE 2

FACTOR - FACTOR PRINCIPLE

Factor - Product Principle

In this discussion the process rays developed in the last section will again be used. The four process rays are again illustrated in Figure 3. If the level of factor X_1 is held at a constant level, Ox_1 in Figure 3, then the output level varies with the input of factor X_2. This is accomplished through shifts from one process ray to another. If the output level is plotted against the input level of X_2 the production function illustrated in Figure 4 results.

The satisfaction of this principle requires the introduction of a price line. The line AB in Figure 4 represents the price line and with this price line the optimum point is found where Ox_2 of factor X_2 is used and Oy of output Y is produced.

As with the other two conditions, the price line can rotate substantially before the optimum point shifts.

Linear programming does then, with some modification, satisfy the marginal conditions for the equilibrium of the firm.

VIII. AN EXAMPLE OF LINEAR PROGRAMMING

In order to show exactly how linear programming is used in the solution of farm organization problems a brief example will be developed. The figures used in the example have been chosen for illustration purposes only and should not be

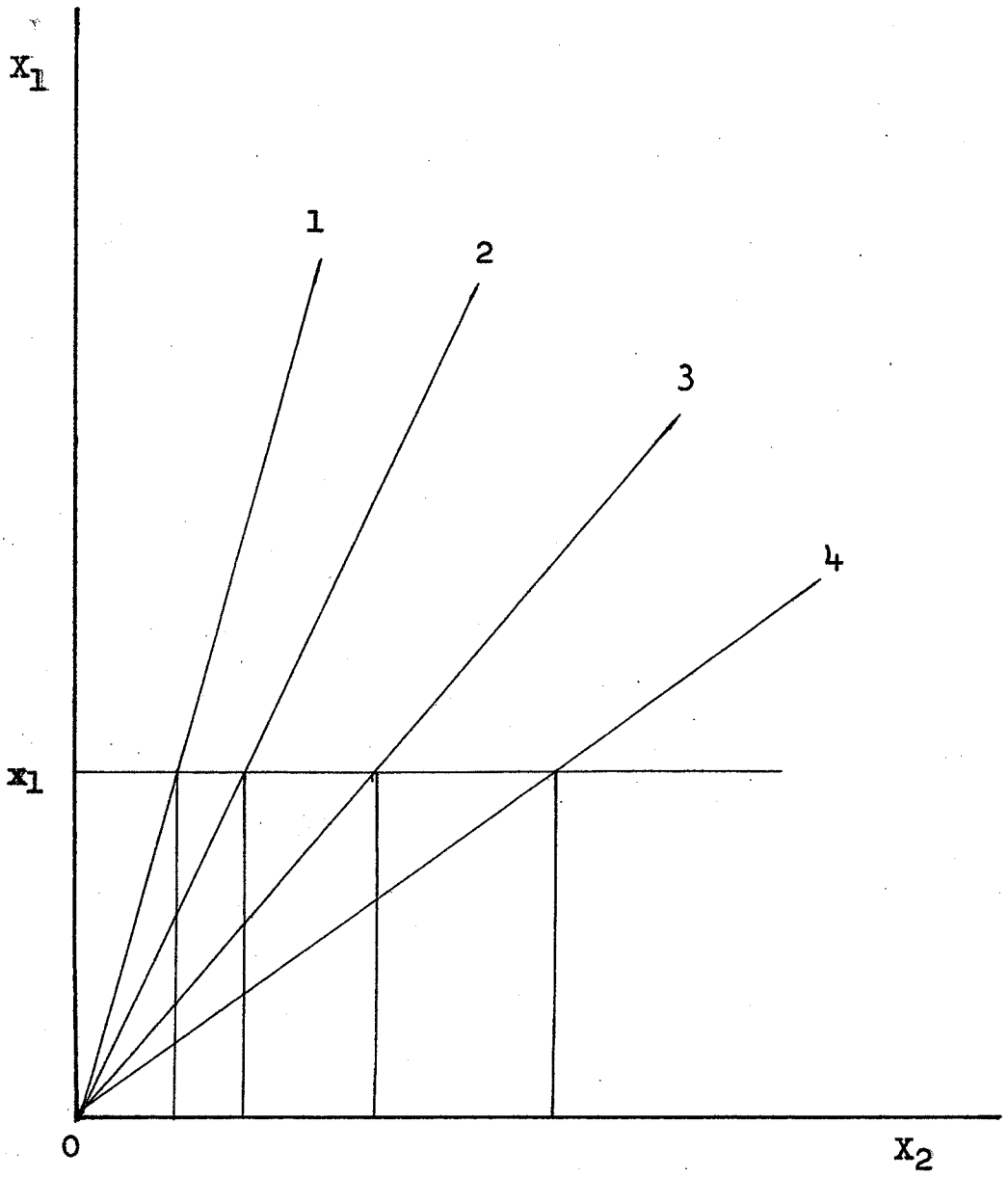

FIGURE 3

DEVELOPMENT OF PRODUCTION FUNCTION

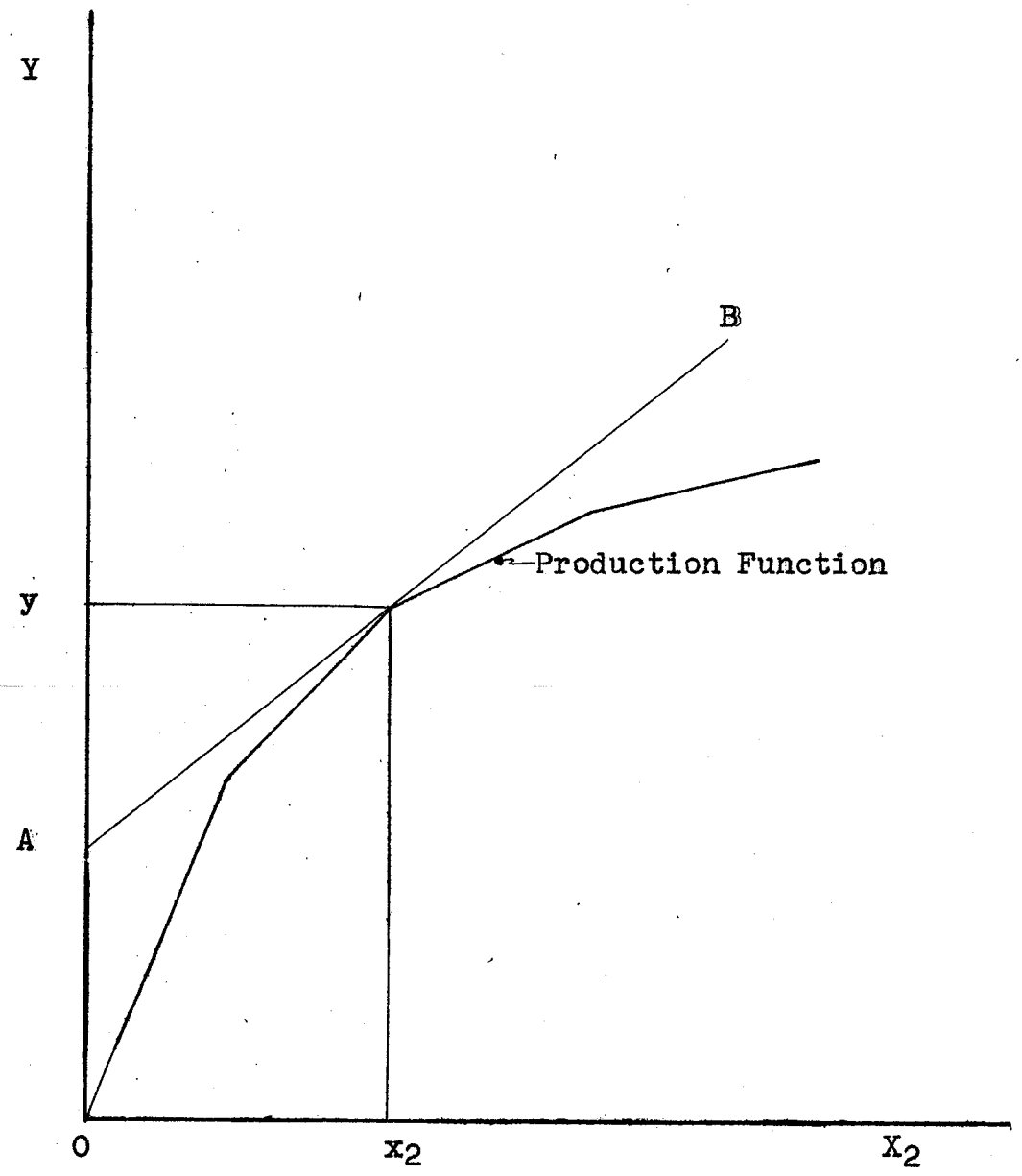

FIGURE 4

FACTOR - PRODUCT PRINCIPLE

considered true figures.

In the example it is assumed that the farm under consideration has at its disposal only two possible enterprises. The enterprises that will be considered are two types of feeder cattle - steer calves and yearling steers. It is further assumed that there are only three restrictive resources - building space, labour and capital. The assumed resource requirements or input - output coefficients for these two enterprises are presented in Table I.

TABLE I

INPUT - OUTPUT COEFFICIENTS FOR STEER CALVES AND YEARLING STEERS

Resource	Requirements Per Head	
	Steer Calves	Yearling Steers
Labour (hrs.)	8	6
Space (sq. ft.)	25	38
Capital ($)	95	150

It is also assumed that the following quantities of the restrictive resources are available:

Labour	600 hours
Capital	$5,000
Space	2,000 sq. ft.

The net prices assumed are $16 for steer calves

and $30 for yearling steers.

The first step is to set up the necessary system of inequalities. In the example this will be:

$$8X_1 + 6X_2 \leq 600$$
$$25X_1 + 38X_2 \leq 2{,}000$$
$$95X_1 + 150X_2 \leq 5{,}000$$

In this system X_1 is the number of steer calves included in the plan and X_2 the number of yearling steers.

Since inequalities are very difficult to work with, three more activities are added to the system so that it can be converted to a system of equalities. These three additional activities are:

X_3: a disposal activity for labour

X_4: a disposal activity for space

X_5: a disposal activity for capital

A disposal activity in the production plan at the level 50 allows 50 units of the resource to remain idle. With these three activities the system becomes a system of equalities because any resource not used by the real activities can enter these disposal activities and remain unused.

The system of equalities now becomes:

$$8X_1 + 6X_2 + 1X_3 + 0X_4 + 0X_5 = 600$$
$$25X_1 + 38X_2 + 0X_3 + 1X_4 + 0X_5 = 2000$$
$$95X_1 + 150X_2 + 0X_3 + 0X_4 + 1X_5 = 5000$$

The profit function to be maximized is written:

$$Z = 16X_1 + 30X_2 + 0X_3 + 0X_4 + 0X_5$$

In this equation X_1 represents the number of steer calves included in the final plan, X_2 the number of yearling steers and X_3, X_4 and X_5 the levels of the three disposal activities. The numerical values in the equation represent the net prices of one unit of each of the activities. As can be seen from the equation the net price assigned to the disposal activities is zero. To find the return realized from any enterprize the net price is multiplied by the level at which the enterprise is included in the plan. The Z value is then the total return realized by the production plan. Linear programming is used to determine the values of X_1, X_2, ..., X_5 that will maximize Z.

The program is now ready to be set up. The procedure used is to set up a feasible production plan and then to attempt to change it in such a way that profit is increased. The usual starting point is a plan which contains all the disposal activities at such a level that all the resources are used by these activities. In the example in Table II this is set up in section I.

The next step is to calculate the Z or opportunity cost row. This will be more fully discussed later and it is sufficient to say that each coefficient represents the gross loss of return through the introduction of one unit of that enterprise.

TABLE II

AN EXAMPLE OF LINEAR PROGRAMMING

CC	Enterprise	Code	C ⟶ Amount of Enterprise P_0	0 P_3	0 P_4	0 P_5	16 P_1	30 P_2	R	
				Disposal Activities			Real Activities			
00	Labour	P_3	600	1	0	0	8	6	100	Section I
0	Space	P_4	2,000	0	1	0	25	38	53	
0	Capital	P_5	5,000	0	0	1	95	150	33	
	Z		0	0	0	0	0	0		
	Z-C		0	0	0	0	-16	-30		
0	Labour	P_3	400	1	0	-0.004	4.202	0		Section II
0	Space	P_4	733	0	1	-0.252	0.946	0		
30	Yearling Steers	P_2	33	0	0	0.007	0.633	1		
	Z		1,000	0	0	0.200	19,000	30		
	Z-C		1,000	0	0	0.200	3.000	0		

The Z - C row must then be calculated. The C row is the net price of a unit of an enterprise so that the Z - C row is the net gain or loss of return through the introduction of one unit of the enterprise.

The enterprise with the most negative Z - C (greatest net gain in return per unit introduced) is selected to enter the new production plan.[19/] In the example the yearling steer enterprise will be selected. By dividing the resource restrictions in the P_o column by the input - output coefficients in the outgoing column (P_2) the maximum amount of the incoming enterprise that can be produced with each of the resources is determined. These results are entered in the R column. The resource restriction for which the R value is the smallest is the most limiting factor. It is then chosen as the resource to be replaced. That is the new enterprise (P_2) is brought into the program at a level which will just use up all of the most limiting resource.

The next step is to calculate the incoming row, P_2 in section II of the example. Illustrating the computational procedure used for one coefficient in this row will suffice to show how this row is calculated.

19/ Since Z is the opportunity cost and C the net price then a negative Z - C means that the net price exceeds the opportunity cost. A positive Z - C coefficient means that return is reduced by the introduction of that enterprise.

In calculating the coefficient for the P_1 column for the incoming row the coefficient at the intersection of the outgoing row and the P_1 column is divided by the pivot figure (the figure at the intersection of the outgoing row and the outgoing column). The coefficient to be entered is:

$$\frac{95}{150} = .633$$

The logic behind this is that if the steer calves are to be introduced into a future program it must take capital away from the yearling steer enterprise. Since one unit of the steer calf enterprise uses as much capital as .633 units of the yearling steer enterprise it becomes necessary to reduce the yearling steer enterprise by .633 for every unit the steer calf enterprise is increased. The other coefficients in the incoming row can be similarly interpreted.

All other coefficients of section II are calculated using the following formula:

$$a'_{ij} = a_{ij} - \left(\frac{a_{rj}}{a_{rk}}\right) a_{ik}$$

In the equation i represents any row, j any column, r the outgoing row of the old matrix and k the outgoing column of the old matrix. Thus $\frac{a_{rj}}{a_{rk}}$ is the coefficient found in the incoming row and the j column of the new matrix.

Using this formula for the calculation of a labour coefficient for the steer calf enterprise we have:

$$\begin{aligned} a'_{ij} &= 8 - \left(\frac{95}{150}\right) 6 \\ &= 8 - .633(6) \\ &= 8 - 3.798 \\ &= 4.202 \end{aligned}$$

As explained above for every unit of the steer calf enterprise introduced .633 units of the yearling steer enterprise must be removed. Since one unit of the yearling steer enterprise uses 6 hours of labour this removal makes available 3.798 hours of labour. Thus to increase the steer calf enterprise by one unit only 4.202 hours of the previously unused labour must be used. All other coefficients in section II can be similarly interpreted.

The Z row of section II must now be calculated. The coefficient for each column is determined by finding the value of the summation of the products of the prices of each enterprise multiplied by the coefficients found in the same row as the enterprise and in the column for which the Z coefficient is being determined. For the steer calves the Z coefficient is calculated:

$$Z = \$0(4.202) + \$0(0.946) + \$30(0.633) = \$19.00$$

For each unit of the steer calf enterprise introduced 4.202 units of labour disposal are removed, 0.946 units of space disposal and 0.633 units of yearling steers. The disposal activities have no price but the removal of 0.633 units of yearling steers reduces the return by $19.00. This is then the opportunity cost of one unit of the steer calf enterprise. In the example this opportunity cost is greater then the net price, that is the Z - C is positive. Total return cannot be increased by the introduction of steer calves into the program.

For section II all Z - C coefficients are positive. This means that no changes can be made in the production plan which will increase the total returns. This then is the optimum plan. It includes 33 head of yearling steers, allows 400 hours of labour and 733 square feet of space to remain idle and yield a return of $1,000.

In a more complex example of linear programming the final plan would be determined only after several sections were calculated in exactly the same manner as the second section of the example. All the necessary principles and techniques that would be used in any larger program have been illustrated in this example.

CHAPTER III

ANALYTICAL PROCEDURE

Linear programming is a useful tool for the solution of several of the problems facing agricultural economists. It has been used in determining cost minimizing production processes, to specify spatial equilibrium patterns in the flow of agricultural products, to determine optimum interregional patterns of resource use and product specialization and to determine optimum farm organization of resources and enterprises.[1/] In this present study linear programming was used in the solution of the problems of the individual firm of agriculture, that is, optimum farm organization. Since this is the case the first step in the analytical procedure is the selection of a base farm.

After the base farm has been selected different farm organizations will be developed for this farm and the relative merits of each evaluated. In this way the hypotheses presented in the introductory chapter can be tested. The base farm selected must be typical of the area under study. Only if this is so will the conclusions drawn from the study be applicable to farms in the area other than the one being

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1/ E.O. Heady and W. Candler, Linear Programming Methods (Ames, Iowa State College Press, 1958), Pg. 1.

used in the study. This is the case study approach - the organization of one farm is studied in detail and generalizations are drawn from the analysis about farm organization on all similar farms. There are two approaches which can be used in the selection of a base farm: (1) development of a hypothetical base farm and (2) selection of an existing farm unit as the base farm.

I. DEVELOPMENT OF A HYPOTHETICAL BASE FARM

Using this approach a hypothetical base farm considered typical of the area under study is developed. This requires that a sample of the farms in the area be taken. From this sample information about the nature of the farm business is collected. Using this information and statistical procedures, principally averaging, a hypothetical base farm is synthesized.

The base farm developed in this manner is statistically typical of the area under study. The major advantage of this method is that the base farm is selected objectively.

This "average" farm, while generally representative of the area, may include conditions that could not arise on any given farm in a practical situation. For example the "average" farm so developed may have available several small buildings each suitable for the production of a different livestock enterprise. This may be the result of averaging the available building space on a number of farms each of which has available

only one large building suitable for one kind of livestock production. If unusual or special conditions result from the averaging it is very difficult to defend the results of the study as practical.

II. SELECTION OF AN EXISTING FARM UNIT AS THE BASE FARM

If this second method is used the danger of including impractical situations is overcome. The base farm is actually operating and the conditions included can be used under "real" conditions. Using this method however it is necessary that the farm chosen does not exhibit any special characteristics. The farm must not have at its disposal unusually large or unusually small amounts of any resource relative to that available on other farms in the area. Thus the farm selected must be one that could be considered typical of the area. If care is exercised a fairly typical farm can be chosen without too much difficulty. The farm chosen will not be statistically typical of the area and the selection will involve some subjective judgments. If the selection is made carefully these difficulties can be overcome.

III. DESCRIPTION OF FARM SELECTED

Soil

The farm selected is located entirely on Red River Clay

soil - the soil type under study. The land on which the farm is located is almost all classified as either IId or IIId soil. IId soil is described as land of good productivity which is imperfectly drained. Land of moderate productivity on which drainage is a problem is classified as IIId land.[2/] Red River Clay is classified as either IId or IIId. This farm then fulfills a very important requirement - that the soil type be typical of the area under study.

Farm Size

The farm includes 708 acres of land, 639 acres of which is suitable for crop production. The farm is probably somewhat larger than the average farm on Red River Clay. In 1959 the average farm size of 74 farms on soil types similar to Red River Clay was 536 acres, 487 of which was suitable for crop production.[3/] The farm however is not excessively large and can still be considered fairly typical of the Red River Clay soil zone.

Enterprises Used on the Farm

Crops. The farm at present produces only three crops:

2/ Soils and Crops Branch, Manitoba Department of Agriculture, Manual For Land Use Mapping 1959.

3/ J.P. Hudson, 1959 Annual Report of the Carmen District Farm Business Association (Department of Agricultural Economics and Farm Management, University of Manitoba, June, 1960).

wheat, oats and hay. There are no special crops produced on this farm. Many of the farmers on Red River Clay do produce special crops. There are such a variety produced however that none could be selected as typical of the area. Barley production is also excluded on this farm. This exclusion need not make the farm any less typical because the three basic grain crops (wheat, oats and barley) are usually considered quite interchangeable as far as usefulness as feed or profit realized is concerned.

Livestock. The only livestock enterprise included in the farm plan at present is a cattle finishing operation. This cannot be considered typical of the farms in the area. One of the objectives of this study is to determine the place of cattle finishing enterprises in the farm organization on Red River Clay. The inclusion of this enterprise is therefore beneficial rather than undesirable.

Labour Supply

All the labour used on the farm is supplied by the owner operator and a full time hired man. No unpaid family labour is available. The total labour available is 5,257 hours. This is slightly above the average amount available on 74 farms on similar soil types. The average on the 74 farms was 4,869 hours.[4/] This difference does not seem to be large

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4/ Ibid.

enough to make the farm any less typical of the area.

Buildings and Machinery

There is available on the farm a complete complement of machinery and buildings necessary for the production of the three crops and the cattle finishing enterprise. There is no specially large or unusual equipment used on the farm but all essential equipment is available. The building now used for the cattle finishing enterprise could be converted for use in a cow - finished calf enterprise. This is important because it is one of the objectives in this study to determine the place of the cow - finished calf enterprise in the study area as well as the place of the cattle finishing enterprise.

After the farm was selected it was necessary to set up three sets of data: (1) resource restrictions, (2) possible enterprises, and (3) input - output coefficients. As pointed out in Chapter II it is impossible to compute linear programs without this information.

IV. RESOURCE RESTRICTIONS

The basic resource restrictions which were used in the majority of the programs are listed in Table III.

TABLE III

RESOURCE RESTRICTIONS

Cropland	639 acres
Spring labour	868 hours
Summer labour	995 hours
Fall labour	1,150 hours
Winter labour	2,244 hours
Covered cattle space	6,000 square feet
Capital	$38,000

Cropland Acres

The 639 acres is land that can be included in a crop rotation. It thus includes all land in grain or hay production plus any land devoted to summer fallow.

Spring Labour

The spring season is assumed to run from the first of May to the fifteenth of June. During this period all spring work necessary for crop production is assumed to be completed. The 868 hours available is made up by two men each working eleven hours a day, six days a week.

Summer Labour

The summer season used in the study runs from the

fifteenth of June to the fifteenth of August. In this period it is assumed that the hay is put up, the crops sprayed and the summerfallow done. The 995 hours available consists of two men each of whom work 9.5 hours a day, six days a week.

Fall Labour

During the fall season, August fifteenth to October fifteenth, all harvesting operations are carried out. The 1,150 hours available for this period are made up by two men each of whom work eleven hours a day, six days a week.

Winter Labour

The remainder of the year (October fifteenth to April thirtieth) is classified as the winter season. In this season most of the labour is available for livestock production. The 2,244 hours is made up by one man working eight hours per day, seven days a week and the other averaging three and one-half hours per day, seven days a week.

Covered Cattle Space

This is made up of the barn space available on the farm.

Capital

The $38,000 of capital available is operating capital. It is to be used for paying the cash expenses incurred by the farm. It does not refer to the value of the fixed

assets. The $38,000 was slightly higher than the amount of expenses incurred on the farm in 1960. The farmer felt however that the figure could be raised to $38,000, that is he could obtain $38,000 of operating capital.

V. POSSIBLE ENTERPRISES

The next step in the procedure was to set up the possible enterprises that would be considered in the study. The enterprises selected are divided into three groups: (1) crop rotations, (2) livestock enterprises and (3) grain and hay buying and selling activities.

Crop Rotations[5/]

There are nine basic crop rotations. For each rotation there is included in the study two enterprises, one in which no fertilizer is used and one in which fertilizer is used at recommended rates.[6/] There is a maximum of four different uses to which land may be put in any one rotation. The four uses are: (1) wheat production, (2) oat production, (3) hay production and (4) sweet clover summerfallow. The only hay produced is an alfalfa brome mixture. In Table IV the

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5/ The rotations as set up were checked by John Peters of the Soils and Crops Branch, Manitoba Department of Agriculture.

6/ Fertilizer recommendations made by Dr. R.A. Hedlin of the Soils Department, University of Manitoba.

TABLE IV

EXPECTED YIELDS AND FERTILIZER USE 1/

Crop	Expected Yield (Per Acre)		Fertilizer Use	
	Without Fertilizer	Fertilized at Recommended Rate	Kind	Amount lbs. per acre
First crop wheat	25 bus.	29 bus.	11-48-0	45
Second crop wheat	20 bus.	25 bus.	16-20-0	100
First crop oats	30 bus.	40 bus.	23-23-0	80
Second crop oats	30 bus.	40 bus.	23-23-0	80
Hay (1st. year, 2 cuts)	2.0 tons	2.5 tons	11-48-0	100
Hay (2nd. year, 2 cuts)	2.0 tons	2.5 tons	Nil	
Hay and break (1 cut)	1.5 tons	1.8 tons	Nil	

1/ Information supplied by Dr. R.A. Hedlin, Soils Department, University of Manitoba.

expected yields of different crops and the fertilizer use are presented.

The crops listed in Table IV are the only ones considered in the study. The crop rotations developed are simply different combinations of the above crops. The only other land use considered is sweet clover summerfallow.

The rotations used as possible enterprises are as follows:

Rotation I. A five year rotation containing wheat - wheat - oats - oats - sweet clover summerfallow. This rotation contains 20 percent legumes. This is the minimum amount of grass or legumes that agronomists feel is advisable on Red River Clay soils. It is in fact below the usually recommended minimum of 25 percent on class IId land and 33.33 percent on class IIId land.

Rotation II. A four year rotation, wheat - wheat - oats - sweet clover summerfallow. This rotation contains 25 percent legumes.

Rotation III. A six year rotation containing 33.33 percent grass and legumes, wheat - wheat - oats - oats - hay - hay.

Rotation IV. An eight year rotation wheat - wheat -

oats - sweet clover summerfallow - wheat - wheat - hay - hay. This rotation contains 37.5 percent grass and legumes.

Rotation V. A five year rotation containing 40 percent grass and legumes, wheat - wheat - oats - hay - hay.

Rotation VI. An eight year rotation including 50 percent grass and legumes, wheat - oats - hay - hay - hay - wheat - oats - sweet clover summerfallow.

Rotation VII. A five year rotation containing 60 percent grass and legumes, wheat - oats - hay - hay - hay.

Rotation VIII. This is the rotation which the farmer is at present using on his farm. It is also considered by agronomists to be the most desirable as far as soil management is concerned. It is a ten year rotation containing 40 percent grass and legumes, wheat - wheat - oats - hay - hay - hay - wheat - wheat - oats - sweet clover summerfallow.

Rotation IX, This is a six year rotation which includes 50 percent grass and legumes, wheat - wheat - oats - hay - hay - hay.

One of the objectives set out in the introductory chapter was to determine the place of forage production on

Red River Clay. This is why the rotations chosen have a wide range of forage level. They range from the minimum allowed by agronomists (20 percent) to a maximum of 60 percent. Although many other rotations could have been chosen it was felt that these nine provided an adequate range.

Livestock Enterprises

The only livestock enterprises considered in this study are beef cattle enterprises. Both cattle finishing enterprizes and cow - finished calf enterprises are considered. There are many other types of livestock enterprises that are carried out by farmers on Red River Clay which are not considered in the study. There are a substantial number of farmers on Red River Clay who have included in the farm organization poultry flocks, hog enterprises or dairy herds. Beef cattle enterprises seem to be the livestock enterprises most commonly carried out in the area. For this reason and as was pointed out earlier one of the objectives of this study is to determine the place of cattle finishing enterprises and cow - finished calf enterprises on Red River Clay only beef enterprises are considered.

Cattle Finishing Enterprises

For cattle finishing enterprises, cattle that have been raised on a high forage ration and which are in a unfinished

condition are purchased. These cattle are then fattened or finished for slaughter. These cattle can be purchased at different ages and thus at different weights and stages of development. There are therefore different types of cattle which can be used in this type of enterprise. For this study five of these types are considered. These five classes include the types of cattle most often used in cattle finishing enterprises. For each of these classes two enterprises have been developed. In the first the cattle are fed a high - grain - low - forage ration (2 grain : 1 hay), and in the second they are fed a medium grain ration (1 hay : 1 grain). These classes are :

Steer Calves. These are purchased at about 430 pounds and fattened to 810 pounds. This 380 pound gain takes 200 days on the medium grain ration and 181 days on the heavy grain ration.

Heifer Calves. These calves are also purchased after weaning at about 400 pounds. They are then fattened until they weigh 750 pounds. This takes 195 days on the medium grain ration or 175 days on the heavy grain ration.

Yearling Steers. These are bought as yearlings weighing 710 pounds and sold when they reach a weight of 1,010 pounds. It requires 150 days on the medium grain

ration or 136 days on the heavy grain ration to accomplish this gain.

Yearling Heifers. The purchase weight of this class is approximately 680 pounds and the sale weight 950 pounds. These heifers are on either the medium grain ration for 130 days or the heavy grain ration for 119 days.

Two Year Old Steers. These steers are fattened from 890 pounds to 1,150 pounds. The steers are fed 125 days on the medium grain ration or 113 days on the heavy grain ration.

Cow - Finished Calf Enterprises

In the cow - finished calf enterprises there is a cow herd maintained on the farm. The calves are raised from birth to slaughter. There are several different feeding regimes on which the calves produced can be readied for market. In this study four cow - finished calf enterprises are considered. In each of these the calves are raised in an identical manner to weaning age (6.5 months). After weaning the calves are prepared for market on one of the four following regimes. Each regime constitutes a separate enterprise.

Finished Calves Medium Grain. Both the steer calves and the heifer calves are put directly into the feedlot after weaning. The steers are fattened from 430 pounds to

750 pounds in 195 days. Both the steers and heifers are fed a medium grain ration (1 hay : 1 grain).

Finished Calves Heavy Grain. This is exactly the same regime as that immediately above except that a heavy grain ration (2 grain : 1 hay) is used rather than the medium grain ration. The steers are fed 181 days and the heifers 175 days.

Overwinter and Fatten. Under this plan the steers are overwintered on a high forage ration and then put into the feedlot for 155 days where they are fed a medium grain ration. The steers are sold weighing about 860 pounds. The heifers are also overwintered on a high forage ration but they are then pastured for 45 days in the first part of the pasture season before being fattened for 90 days. They are fattened on a medium grain ration and sold when weighing 740 pounds.

Twenty - two Month Plan. Both the steers and heifers are overwintered on a high forage ration, pastured the full season and fattened on a medium grain ration for about five months. The heifers are sold weighing 995 pounds and the steers weighing 1,050 pounds.

Buying and Selling Activities

Enterprises have also been set up which allow oats and wheat to be purchased and oats, wheat and hay to be sold.

These enterprises listed above include all the enterprises considered in the study. No other enterprise will be allowed to enter the farm plan.

VI. INPUT - OUTPUT COEFFICIENTS

This is the final set of data required for the study. For each of the above enterprises it was necessary to develop a complete set of input - output coefficients. The coefficients that were used in the study are presented in Table I of the appendix. The coefficients used were calculated from a handbook developed by the Department of Agricultural Economics and Farm Management at the University of Manitoba.[8/] In collecting data for this handbook a great variety of sources were drawn on. The coefficients are not perfect but they are the best that could be found.

One important consideration is whether or not the coefficients used are appropriate on the base farm used in the study. In order to verify this completely it would be necessary to do a detailed study on the resource requirements

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8/ "Farm Management Handbook", Department of Agricultural Economics and Farm Management, University of Manitoba, (Unpublished).

of each enterprise under the conditions present on the farm. This is beyond the scope of the present study. Verification for this study consisted of consultation with various agricultural experts. The coefficients were passed as satisfactory for use on the farm in question.

One further note regarding coefficients should be added. The prices used in all enterprises were based on the following averages:

Grain prices 1945-1958

Cattle prices 1946-1959.

VII. PROGRAMS USED IN THE STUDY

After the resource restrictions, possible enterprises and input - output coefficients were set up the computations could be carried out. It then became necessary to set up exactly what programs would be done. The programs are divided into groups. Each group is designed to fulfill one of the objectives as listed in the introductory chapter.

General Programs

In this section two programs have been computed. These programs are designed to determine the overall optimum and to provide a basis of comparison for the other programs in the study.

P_1. This first program was designed to determine the overall farm plan which would result in the maximum return. All enterprises listed in section V of this chapter were included and the resource restrictions were entered at the levels listed in Table III.

P_2. This program was designed to determine the optimum farm plan using only the enterprises presently included in the plan. Thus only rotation VIII was allowed to compete. Both the fertilized and the unfertilized enterprises were allowed to compete. The only livestock enterprises considered were the five cattle finishing enterprises. The grain and hay selling activities were included, but no buying activities were included as the farmer has not been purchasing grain.

Comparing the Return From Various Levels of Grass and Legumes in the Rotation

In this section eighteen programs were calculated. Each program was designed to find the optimum farm plan when only one rotation enterprise was allowed to enter the farm plan. From this it can be determined how the level of grass included in the rotation affects the return received. In each program of this section only one of the eighteen rotation enterprises are allowed to enter the final plan. All livestock and all buying and selling activities are considered. In all programs the resource restrictions are held at the

levels presented in Table III. In the presentation of the programs considered in this section only the rotation enterprise considered is listed. As stated above the programs are similar in all other respects. The programs are:

P_3. Rotation I fertilized.
P_4. Rotation I unfertilized.
P_5. Rotation II fertilized.
P_6. Rotation II unfertilized.
P_7. Rotation III fertilized.
P_8. Rotation III unfertilized.
P_9. Rotation IV fertilized.
P_{10}. Rotation IV unfertilized.
P_{11}. Rotation V fertilized.
P_{12}. Rotation V unfertilized.
P_{13}. Rotation VI fertilized.
P_{14}. Rotation VI unfertilized.
P_{15}. Rotation VII fertilized.
P_{16}. Rotation VII unfertilized.
P_{17}. Rotation VIII fertilized.
P_{18}. Rotation VIII unfertilized.
P_{19}. Rotation IX fertilized.
P_{20}. Rotation IX unfertilized.

Returns of Fertilizer

In this section the objective is to determine whether

or not the fertilizer recommendations used in the study are profitable. The programs computed for the previous section were also used in this section. From them returns realized from an unfertilized rotation can be compared with those realized from its fertilized counterpart. It is possible that the true optimum includes a combination of the fertilized rotation and the unfertilized rotation. For this reason nine additional programs were calculated. In each of these programs a fertilized rotation and the same rotation unfertilized were allowed to compete with all the livestock activities used in the study and all buying and selling activities. The resource restrictions were held at the levels given in Table III. Again only the rotation enterprises considered are listed in the presentation of the programs. The programs are:

P_{21}. Rotation I fertilized and rotation I unfertilized.

P_{22}. Rotation II fertilized and rotation II unfertilized.

P_{23}. Rotation III fertilized and rotation III unfertilized.

P_{24}. Rotation IV fertilized and rotation IV unfertilized.

P_{25}. Rotation V fertilized and rotation V unfertilized.

P_{26}. Rotation VI fertilized and rotation VI unfertilized.

P_{27}. Rotation VII fertilized and rotation VII unfertilized.

P_{28}. Rotation VIII fertilized and rotation VIII unfertilized.

P_{29}. Rotation IX fertilized and rotation IX unfertilized.

Fertilizer Use Under Present Situation

Two additional programs were added to this section in order to show how fertilizer use affected the return if the farmer retained the limitations presently in effect on the enterprises considered. The resource restrictions were held at the levels given in Table III.

P_{30}. Rotation VIII fertilized was allowed to compete with the five cattle finishing enterprises and the selling activities.

P_{31}. Rotation VIII unfertilized was allowed to compete with the five cattle finishing enterprises and the selling activities.

Returns From Various Livestock Activities

In this section the objective was to determine the place of different livestock enterprises on Red River Clay. In this section strategic livestock enterprises were allowed to compete with all rotation enterprises. The hay selling

activity was not included. The program must thus select the most profitable combination of rotations together with the given livestock enterprise. All hay produced must either be fed or left unused. In all the programs the resource restrictions are held at the level given in Table III. In the presentation of the programs below only the livestock enterprises to be considered are listed. In all the programs the grain buying and selling activities and all the rotation enterprises are allowed to compete. The programs are:

P_{32}. All livestock enterprises were included. This was designed to determine the most profitable combination of livestock enterprises when the hay selling activity was excluded.

P_{33}. All cattle finishing enterprises were included. This will determine the most profitable combination of cattle finishing enterprises.

P_{34}. All cow-finished calf enterprises were included. This will determine the most profitable combination of cow - finished calf enterprises.

P_{35}. Steer calves heavy grain.

P_{36}. Steer calves medium grain.

P_{37}. Yearling steers heavy grain.

P_{38}. Yearling steers medium grain.

P_{39}. Two year old steers heavy grain.

P_{40}. Two year old steers medium grain.

P_{41}. Finished calves heavy grain.

P_{42}. Finished calves medium grain.

P_{43}. Overwinter and fatten.

P_{44}. Twenty - two month plan.

A further program was calculated for this section. P_{45} allows only the rotations and the buying and selling activities to compete. No livestock enterprises were included. This program will show how much is gained by including livestock in the production plan.

Variable Resources

The objective in this section was to determine how varying levels of strategic resources would effect the returns. Five programs were done in which the capital level was varied and one in which the winter labour was changed. In each program all resources other than the one which the one which was changed were held at the levels given in Table III. In each program all enterprises were allowed to compete.

Capital. The capital level was allowed to vary from $10,000 to $30,000. No programs were done above $30,000 because after this level the capital was no longer a limiting factor. Thus an increase in the amount of capital available could have no effect on the optimum plan. The programs computed are:

P_{46}. Capital at $10,000.

P_{47}. Capital at $15,000.

P_{48}. Capital at $20,000.

P_{49}. Capital at $25,000.

P_{50}. Capital at $30,000.

Winter Labour. In the additional program (P_{51}) computed here, winter labour is reduced to 1,576 hours. This labour can be supplied by one man working eight hours a day, seven days a week. The second man is then not necessary. All other resources are held at the levels given in Table III. All enterprises are allowed to compete.

Effect of the Exclusion of the Hay Selling Activity

It was noticed that in most of the programs calculated the hay selling activity was included. In some years it is quite possible that this activity could not practically be included in the production plan as no market would exist. It was decided to calculate some programs without including this activity to see what effect this would have on the farm organization. In this section four programs were calcualted. The first (P_{52}) allows all enterprises except hay selling to compete. Resource restrictions were held at the levels given in Table III. In the other three programs "key" rotations were allowed to compete with all livestock enterprises and all grain buying and selling activities.

These programs were:

P_{53}. Rotation IV fertilized was the only rotation included.

P_{54}. Rotation VIII fertilized was the only rotation included.

P_{55}. Rotation IX fertilized was the only rotation included.

Effect of a Rising Price for Feeder Calves

Many agriculturists, especially animal scientists feel that due to the recent increase in the number of cattle finishing enterprises being introduced the price of feeder calves will rise. The programs calculated for this study indicated that cattle finishing enterprises were important in that they were often included in the optimum plans determined. Thus two programs were done in which the price of the purchased cattle was raised. This results in an increase in the operating expenses of the cattle finishing enterprises and thus a decrease in the net price. This also increases the capital requirements of each of these cattle finishing enterprises. In the programs all enterprises were allowed to compete and the resource restrictions were held at the levels given in Table III. The programs calculated for this last section are :

P_{56}. Feeder cattle price raised 5 percent.

P_{57}. Feeder cattle price raised 10 percent.

No programs were done in which the price was raised more than ten percent because the final plan of P_{57} included no cattle finishing enterprises. Thus decreasing the return of these enterprises further could have no effect on the final plan.

CHAPTER IV

ANALYSIS OF RESULTS

The results will be discussed in six sections. These sections will correspond to the groupings used in the presentation of the programs in Chapter III.

For each section of the chapter two tables will be presented which list the results of the programs computed for that section. The first table presents the optimum plan selected by the program and the financial summary for that plan. In the financial summary, the receipts, expenses and net return for each enterprise in the plan are presented. The return is not a profit figure but is the return to the fixed resources included in the resource restrictions of the program. No receipts are realized from rotation enterprises. The production from these enterprises is transferred either to the livestock activities or to the selling activities. No charge is made for this transfer. Also no expenses are charged to the selling activities. Any marketing expenses that would be incurred are deducted from the selling price.

In the second table the resource use data are presented. The amount of each resource available, used and left over in each program is listed. In addition this table presents information as to the disposition of the crop production.

The amount of each crop listed as available in the table is the amount produced by the rotation enterprises included in the final plan. The amount presented as used in the table is that fed to the livestock.

I. GENERAL

The results of the two programs calculated for this section are presented in Tables V and VI.

The first program computed (P_1) allowed all enterprises used in the study to compete. The resource restrictions were held at the levels given in Table III. The final plan selected by this program is the overall optimum plan for the farm. The final plan includes 240 head of steer calves fed a medium grain ration and 639 acres of rotation IX fertilized. The grain and hay produced but not used by the livestock is sold. Further expansion of the enterprises was limited by the amount of land and building space available. The return realized from this production plan was equal to $16,554.92. This production plan represents the combination of rotation enterprises and livestock enterprises which results in the maximum return to the available resources.

In the second program calculated (P_2) for this section the optimum farm plan given the present restriction on enterprises is determined. The only rotation considered is rotation VIII, the rotation now being used on the farm. The

TABLE V

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_1 AND P_2

Program	Enterprises Included In The Final Plan	Enterprise Level	Receipts $	Expenses $	Return $
P_1	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	257 bus.	163.45	-	163.45
	Sell hay	500 tons	4,508.00	-	4,508.00
		Total	45,146.49	28,591.57	16,554.92
P_2	Rotation VIII fertilized	639 acres	-	6,064.11	-6,064.11
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	211 tons	1,902.38	-	1,902.38
		Total	45,852.22	28,859.31	15,992.91

TABLE VI

RESOURCES AVAILABLE, USED, AND LEFT OVER,

PROGRAMS P_1 AND P_2

Program	Resource									
	Land Acres	Spring Labour Hrs.	Summer Labour Hrs.	Fall Labour Hrs.	Winter Labour Hrs.	Covered Cattle Space Sq. Ft.	Capital $	Wheat Bus.	Oats Bus.	Hay Tons
P_1										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	261	300	466	2,168	6,000	28,594	4,516	3,826	224
Sold	-	-	-	-	-	-	-	995	257	500
Left over	0	607	695	684	76	0	9,406	0	0	0
P_2										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	4,899	435
Used	639	318	385	530	2,212	6,000	28,862	4,516	3,826	224
Sold	-	-	-	-	-	-	-	2,098	1,073	211
Left over	0	550	610	620	32	0	9,138	0	0	0

only livestock enterprises considered are the cattle finishing enterprises as the farmer is not prepared at present to produce a cow - finished calf enterprise. Grain and hay selling activities are included but no buying activities are included as the farmer is not buying grain at present. Again the principle livestock enterprise is 240 head of steer calves fed a medium grain ration. The fertilized rotation entered the final plan at 639 acres. The grain and hay not used by the livestock was sold. Further expansion of the enterprises was limited by the land and cattle space available. The return from this program is equal to $15,992.91. This is $562.01 below the overall optimum.

The difference in the return realized by these plans must be attributed to the difference in the crop rotation included. As can be seen in Table VI rotation VIII fertilized produces more grain and less hay than rotation IX fertilized. As a result the expenses incurred by rotation VIII are $267.74 higher than those incurred by rotation IX. As is seen in Table V the amount of grain sold in P_2 is more than that sold in P_1 but the amount of hay considerably less. The return from the selling activities in P_2 are $294.27 less than the returns realized from the selling activities in P_1. Rotation VIII does allow the same livestock enterprise to be included in the final plan. However the crop production left over after this enterprise is included is not as valuable as

that left over when rotation IX is included in the final plan. Coupled with this is the fact that the expenses incurred by rotation VIII are higher than those incurred by rotation IX. The differences could be summarized by stating that the limitations used in P_2 allow a less profitable combination of rotation enterprises, livestock enterprises and selling activities to be included in the final plan.

II. A COMPARISON OF THE RETURN FROM VARIOUS LEVELS OF GRASS AND LEGUMES IN THE ROTATION

For this comparison eighteen programs were calculated. In each of these programs one rotation enterprise is allowed to compete with all livestock enterprises and all the buying and selling activities.

In the first four programs (P_3 to P_6) rotations I and II are considered. Since no hay is produced by these rotations none of the livestock enterprises used in this study could be included in the final plan. In each program the rotation being considered was included at 639 acres. The only limiting resource was land. All of the crop production in each program was sold. Differences in return are then attributed to differences in cash expenses and in crop production.

In programs P_7 and P_8 rotation III was considered. The

TABLE VII

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_3 TO P_{20}

Program	Enterprises Included In The Final Plan	Enterprise Level	Receipts $	Expenses $	Return $
P_3	Rotation I fertilized	639 acres	-	6,844.33	-6,844.33
	Sell wheat	6,614 bus.	10,747.75	-	10,747.75
	Sell oats	9,798 bus.	6,231.53	-	6,231.53
		Total	16,979.28	6,844.33	10,134.95
P_4	Rotation I unfertilized	639 acres	-	4,718.38	-4,718.38
	Sell wheat	5,463 bus.	8,877.38	-	8,877.38
	Sell oats	7,242 bus.	4,605.91	-	4,605.91
		Total	13,483.29	4,718.38	8,764.91
P_5	Rotation II fertilized	639 acres	-	6,465.40	-6,465.40
	Sell wheat	8,267 bus.	13,433.88	-	13,433.88
	Sell oats	6,124 bus.	3,894.86	-	3,894.86
		Total	17,328.74	6,465.40	10,863.34
P_6	Rotation II unfertilized	639 acres	-	4,542.65	-4,542.65
	Sell wheat	6,829 bus.	11,097.12	-	11,097.12
	Sell oats	4,526 bus.	2,878.54	-	2,878.54
		Total	13,975.66	4,542.65	9,433.01
P_7	Rotation III fertilized	639 acres	-	6,780.43	-6,780.43
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,116.88
	Sell oats	4,339 bus.	2,759.60	-	2,759.60
	Sell hay	235 tons	2,118.76	-	2,118.76
		Total	45,353.40	29,575.63	15,777.77

(continued)

TABLE VII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_8	Rotation III unfertilized	639 acres	-	4,363.73	-4,363.73
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	37 bus.	60.12	-	60.12
	Sell oats	2,209 bus.	1,404.92	-	1,404.92
	Sell hay	149 tons	1,343.38	-	1,343.38
		Total	41,666.58	27,158.93	14,507.65
P_9	Rotation IV fertilized	639 acres	-	6,232.81	-6,232.81
	Steer calves medium grain	169 head	27,362.62	16,051.62	11,311.00
	Twenty - two month plan	21 cows	3,623.82	845.42	2,778.40
	Sell wheat	4,749 bus.	7,717.12	-	7,717.12
	Sell hay	47 tons	423.75	-	423.75
		Total	39,127.31	23,129.85	15,997.46
P_{10}	Rotation IV unfertilized	639 acres	-	4,192.48	-4,192.48
	Steer calves medium grain	113 head	18,295.72	10,732.74	7,562.98
	Twenty - two month plan	27 cows	4,659.20	1,086.97	3,572.23
	Sell wheat	4,278 bus.	6,951.75	-	6,951.75
		Total	29,906.67	16,012.19	13,894.48
P_{11}	Rotation V fertilized	639 acres	-	6,595.12	-6,595.12
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	325 tons	2,930.20	-	2,930.20
		Total	45,880.04	29,390.32	16,489.72
P_{12}	Rotation V unfertilized	639 acres	-	4,154.14	-4,154.14
	Steer calves medium grain	221 head	35,781.89	20,990.58	14,791.31
	Twenty - two month plan	6 cows	1,035.38	569.88	465.50
	Sell wheat	1,215 bus.	1,974.38	-	1,974.38
	Sell hay	204 tons	1,839.26	-	1,839.26
		Total	40,630.91	25,714.60	14,916.31

(continued)

TABLE VII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{13}	Rotation VI fertilized	639 acres	-	5,639.81	-5,639.81
	Steer calves medium grain	236 head	38,210.52	22,415.28	15,795.24
	Twenty - two month plan	1 cow	172.56	40.26	132.30
	Sell oats	3,944 bus.	2,508.38	-	2,508.38
	Sell hay	315 tons	2,804.04	-	2,804.04
		Total	43,695.50	28,095.35	15,600.15
P_{14}	Rotation VI unfertilized	639 acres	-	3,941.35	-3,941.35
	Steer calves medium grain	190 head	30,762.71	18,046.20	12,716.51
	Twenty - two month plan	15 cows	2,588.44	603.87	1,984.57
	Sell oats	2,835 bus.	1,803.06	-	1,803.06
	Sell hay	164 tons	1,478.62	-	1,478.62
		Total	36,632.83	22,591.42	14,041.41
P_{15}	Rotation VII fertilized	639 acres	-	5,400.19	-5,400.19
	Steer calves medium grain	172 head	27,848.35	16,336.56	11,511.79
	Twenty - two month plan	20 cows	3,451.26	805.16	2,646.10
	Sell oats	3,081 bus.	1,959.52	-	1,959.52
	Sell hay	575 tons	5,184.20	-	5,184.20
		Total	38,443.33	22,541.91	15,901.42
P_{16}	Rotation VII unfertilized	639 acres	-	3,633.35	-3,633.35
	Steer calves medium grain	136 head	22,019.62	12,917.28	9,102.34
	Twenty - two month plan	31 cows	5,349.45	1,248.00	4,101.45
	Sell oats	2,195 bus.	1,396.02	-	1,396.02
	Sell hay	372 tons	3,353.95	-	3,353.95
		Total	32,119.04	17,798.63	14,320.41
P_{17}	Rotation VIII fertilized	639 acres	-	6,064.11	-6,064.11
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	211 tons	1,902.38	-	1,902.38
		Total	44,852.22	28,859.31	15,992.91

(continued)

TABLE VII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{18}	Rotation VIII unfertilized	639 acres	-	4,117.08	-4,117.08
	Steer calves medium grain	221 head	35,781.89	20,990.58	14,791.31
	Twenty - two month plan	6 cows	1,035.38	241.55	793.83
	Sell wheat	1,215 bus.	1,974.38	-	1,974.38
	Sell hay	108 tons	973.73	-	973.73
		Total	39,765.38	25,349.21	14,416.17
P_{19}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	257 bus.	163.45	-	163.45
	Sell hay	500 tons	4,508.00	-	4,508.00
		Total	45,146.49	28,591.57	16,554.92
P_{20}	Rotation IX unfertilized	639 acres	-	3,832.09	-3,832.09
	Steer calves medium grain	165 head	26,714.99	15,671.70	11,043.29
	Twenty - two month plan	23 cows	3,968.95	925.93	3,043.02
	Sell wheat	1,093 bus.	1,776.12	-	1,776.12
	Sell hay	285 tons	2,569.56	-	2,569.56
		Total	35,029.62	20,429.72	14,599.90

TABLE VIII

RESOURCES AVAILABLE, USED, AND LEFT OVER,

PROGRAMS P_3 TO P_{20}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	Acres	Hrs.	Hrs.	Hrs.	Hrs.	Sq. Ft.	$	Bus.	Bus.	Tons
P_3										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	9,798	0
Used	639	396	345	684	262	0	6,844	0	0	0
Sold	-	-	-	-	-	-	-	6,614	9,798	-
Left over	0	472	650	466	1,982	6,000	31,156	0	0	-
P_4										
Available	639	868	995	1,150	2,244	6,000	38,000	5,463	7,242	0
Used	639	396	345	684	262	0	4,718	0	0	0
Sold	-	-	-	-	-	-	-	5,463	7,242	0
Left over	0	472	650	466	1,982	6,000	33,282	0	0	-
P_5										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	6,124	0
Used	639	371	383	626	256	0	6,465	0	0	0
Sold	-	-	-	-	-	-	-	8,267	6,124	0
Left over	0	497	612	524	1,988	6,000	31,535	0	0	-
P_6										
Available	639	868	995	1,150	2,244	6,000	38,000	6,829	4,526	0
Used	639	371	383	626	256	0	4,543	0	0	0
Sold	-	-	-	-	-	-	-	6,829	4,526	0
Left over	0	497	612	524	1,988	6,000	33,457	0	0	-

(continued)

TABLE VIII (continued)

Program	Resource: Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Capital	Wheat	Oats	Hay
	Acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_7										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	8,165	459
Used	639	344	326	613	2,219	6,000	29,578	4,516	3,826	224
Sold	-	-	-	-	-	-	-	995	4,339	235
Left over	0	524	669	537	25	0	8,422	0	0	0
P_8										
Available	639	868	995	1,150	2,244	6,000	38,000	4,553	6,035	373
Used	639	344	326	613	2,219	6,000	27,162	4,516	3,826	224
Sold	-	-	-	-	-	-	-	37	2,209	149
Left over	0	524	669	537	25	0	10,838	0	0	0
P_9										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	3,062	343
Used	639	375	523	613	2,162	6,000	23,164	3,518	3,062	296
Sold	-	-	-	-	-	-	-	4,749	0	47
Left over	0	493	472	537	82	0	14,836	0	0	0
P_{10}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,829	2,263	280
Used	639	381	525	629	1,825	5,045	16,038	2,551	2,263	280
Sold	-	-	-	-	-	-	-	4,278	0	0
Left over	0	47	470	521	419	955	21,962	0	0	0
P_{11}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	4,899	548
Used	639	305	328	556	2,200	6,000	29,265	4,516	3,826	224
Sold	-	-	-	-	-	-	-	2,098	1,073	324
Left over	0	563	667	594	44	0	8,735	0	0	0
P_{12}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,463	3,621	448
Used	639	318	358	573	2,183	6,000	25,378	4,248	3,621	244
Sold	-	-	-	-	-	-	1,221.5	1,215	0	204
Left over	0	550	637	577	61	0	12,622	0	0	0

(continued)

TABLE VIII (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.		$	bus.	bus.	tons
P_{13}											
Available	639	868	995	1,150	2,244	6,000		38,000	4,453	7,721	543
Used	639	276	351	445	2,183	6,000		28,067	4,453	3,777	228
Sold	-	-	-	-	-	-		-	0	3,944	315
Left over	0	592	644	705	61	0		9,933	0	0	0
P_{14}											
Available	639	868	995	1,150	2,244	6,000		38,000	3,814	6,124	439
Used	639	305	532	486	2,143	6,000		22,611	3,814	3,289	275
Sold	-	-	-	-	-	-		-	0	2,835	164
Left over	0	563	463	664	101	0		15,389	0	0	0
P_{15}											
Available	639	868	995	1,150	2,244	6,000		38,000	3,562	6,177	869
Used	639	252	288	444	2,076	6,000		22,592	3,562	3,096	294
Sold	-	-	-	-	-	-		-	0	3,081	575
Left over	0	616	607	706	168	0		15,408	0	0	0
P_{16}											
Available	639	868	995	1,150	2,244	6,000		38,000	3,051	4,899	702
Used	639	274	435	477	2,044	6,000		17,820	3,051	2,704	330
Sold	-	-	-	-	-	-		-	0	2,195	372
Left over	0	594	560	673	200	0		20,180	0	0	0
P_{17}											
Available	639	868	995	1,150	2,244	6,000		38,000	6,614	4,899	435
Used	639	318	385	530	2,212	6,000		28,861	4,516	3,826	224
Sold	-	-	-	-	-	-		-	2,098	1,073	211
Left over	0	550	610	620	32	0		9,139	0	0	0
P_{18}											
Available	639	868	995	1,150	2,244	6,000		38,000	5,463	3,621	351
Used	639	330	409	547	2,196	6,000		25,341	4,248	3,621	243
Sold	-	-	-	-	-	-		-	1,215	0	108
Left over	0	538	586	603	48	0		12,659	0	0	0

(continued)

TABLE VIII (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{19}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	261	300	466	2,168	6,000	28,594	4,516	3,826	224
Sold	-	-	-	-	-	-	-	995	257	500
Left over	0	607	695	684	76	0	9,406	0	0	0
P_{20}										
Available	639	868	995	1,150	2,244	6,000	38,000	4,553	3,018	586
Used	639	307	396	534	2,101	6,000	20,422	3,460	3,018	301
Sold	-	-	-	-	-	-	-	1,093	0	285
Left over	0	561	599	616	143	0	17,578	0	0	0

final plan for both P_7, which considered the fertilized the rotation and P_8, which considered the unfertilized rotation included the rotation at 639 acres and the steer calves medium grain at 240 head. Any crop production not used by the livestock was sold. In both cases land and cattle space were the limiting factors.

The programs P_9 to P_{16} excluding P_{11} all include the rotation at the full 639 acres and two livestock enterprises - steer calves medium grain and the twenty - two month cow - finished calf enterprise. In each of the programs land and cattle space are limiting factors. In addition production of at least one of the three types of crop production (wheat, oats and hay) is used up entirely by the livestock enterprises. That is in each of the programs at least one of the feed resources is limiting. As these resources become limiting due to the rotation included the livestock enterprises must also be adjusted. When feed is not a limiting factor as with P_1 the most profitable livestock enterprise is 240 head of steer calves fed a medium grain ration. As feed supplies become limiting the optimum farm plan must include a different combination of enterprises.

There are three ways in which the farm plan could be adjusted to overcome this feed shortage. The first is to reduce the level at which the steer calves are included to a point where the most limiting feed resource is just used up. The second is to purchase additional feed necessary to maintain

the livestock enterprise. This only applies in the situation in which wheat or oats are limiting as no hay buying activity was included. The third method is to introduce a livestock enterprise combination that will just use up the most limiting feed resource and also use up the entire cattle space available.

In all of the programs under discussion the third method was the method selected as the alternative which will result in the maximum return to the fixed resources. In each program a combination of the steer calves medium grain enterprise and the twenty - two month plan which will just use up the cattle space and the most limiting feed resource is included.

In P_{11} which considers rotation V fertilized the rotation is included at 639 acres. The feed resources do not limit the livestock enterprises in this program and steer calves medium grain are included at the 240 head level.

Programs P_{17} and P_{19} also include the respective rotation enterprises at 639 acres and the steer calf medium grain enterprise at 240 head. In P_{18} and P_{20} the oats are again a limiting factor. The steer calves in this case are reduced while the twenty - two month plan is increased.

Comparison of the Return Realized From Each Final Plan

In Table IX the returns realized from each program and the amount by which each return falls below the overall

TABLE IX

COMPARISON OF RETURNS REALIZED FROM

PROGRAMS P_3 TO P_{20}

Program	Rotation Considered	Percent of Grass and Legumes Included	Return	Amount Return Is Below Overall Optimum
			$	$
		Fertilized Rotations		
P_3	I	20.0	10,134.95	6,419.97
P_5	II	25.0	10,863.34	5,691.58
P_7	III	33.3	15,777.77	777.15
P_9	IV	37.5	15,997.16	557.76
P_{11}	V	40.0	16,489.72	65.20
P_{13}	VI	50.0	15,600.15	954.77
P_{15}	VII	60.0	15,901.42	653.50
P_{17}	VIII	40.0	15,992.91	562.01
P_{19}	IX	50.0	16,554.92	0
		Unfertilized Rotations		
P_4	I	20.0	8,764.91	7,790.01
P_6	II	25.0	9,433.01	7,121.91
P_8	III	33.3	14,507.65	2,047.27
P_{10}	IV	37.5	13,894.48	2,660.44
P_{12}	V	40.0	14,916.31	1,638.61
P_{14}	VI	50.0	14,041.41	2,513.51
P_{16}	VII	60.0	14,320.41	2,234.51
P_{18}	VIII	40.0	14,416.17	2,138.75
P_{20}	IX	50.0	14,599.90	1,955.02

optimum is presented. From this table it can be seen that the return from the four programs which included no livestock production are substantially below the overall optimum. The differences in return realized by the other programs are not so substantial. In each case it has been possible to combine with the given rotation a combination of livestock enterprises which will result in a return at least approaching that realized by the overall optimum plan. The changes that occur in the livestock enterprises as the rotation is changed point out the importance of a complete farm plan.

If a change in rotation is made it is important that the other enterprises be adjusted to fit with this new rotation in such a way that return is maximized. This section seems to indicate that enough hay must be produced in order that the cattle space available can be fully utilized. The choice of rotation within this limitation does not seem to have too much effect as long as the cattle enterprises are combined with the rotation in such a way that return is maximized.

II. FERTILIZER RETURNS

In this section the programs calculated for the previous section were used to compare the differences in return realized from the fertilized and unfertilized rotation enterprises. Nine additional programs were computed for this section. In

each of these programs a fertilized rotation and its unfertilized counterpart were allowed to compete. These were used to determine whether or not some combination of the fertilized and unfertilized rotations existed which was more profitable than the fertilized rotation alone. The results of these programs are presented in Tables X and XI.

As can be seen from the tables in every case the fertilized rotations used the entire 639 acres of land available. The fertilized rotation is then in every case more profitable than any combination of the unfertilized and fertilized rotations.

The amount spent on fertilizer and the increase in return due to this expenditure is presented in Table XII. Substantial readjustments are necessary in the livestock enterprises when fertilizer is not used. This is especially evident where feed supplies are limiting resources. It is not enough to simply advise that the fertilizer recommendations be used. The farmer must be prepared to adjust his entire farm plan to fit into the new situation. Even though substantial gains can be made by fertilizing at recommended rates it cannot be concluded that this is the most profitable rate of fertilizer application. It is quite possible that there are other rates of application not considered in this study that are even more profitable. From this study it can only be concluded that the profits are greater when fertilizer is used at the recommended rates than when it is not used at all.

TABLE X

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_{21} TO P_{31}

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{21}	Rotation I fertilized	639 acres	-	6,844.33	-6,844.33
	Sell wheat	6,614 bus.	10,747.75	-	10,747.75
	Sell oats	9,798 bus.	6,231.53	-	6,231.53
		Total	16,979.28	6,844.33	10,134.95
P_{22}	Rotation II fertilized	639 acres	-	6,465.40	-6,465.40
	Sell wheat	8,267 bus.	13,433.88	-	13,433.88
	Sell oats	6,124 bus.	3,894.86	-	3,894.86
		Total	17,328.74	6,465.40	10,863.34
P_{23}	Rotation III fertilized	639 acres	-	6,780.43	-6,780.43
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	4,339 bus.	2,759.60	-	2,759.60
	Sell hay	235 tons	2,118.76	-	2,118.76
		Total	45,353.40	29,575.63	15,777.77
P_{24}	Rotation IV fertilized	639 acres	-	6,232.81	-6,232.81
	Steer calves medium grain	169 head	27,362.62	16,051.62	11,311.00
	Twenty - two month plan	21 cows	3,623.82	845.42	2,778.40
	Sell wheat	4,749 bus.	7,717.12	-	7,717.12
	Sell hay	47 tons	423.75	-	423.75
		Total	39,127.31	23,129.85	15,997.46

(continued)

TABLE X (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{25}	Rotation V fertilized	639 acres	-	6,595.12	-6,595.12
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	325 tons	2,930.20	-	2,930.20
		Total	45,880.04	29,390.32	16,489.72
P_{26}	Rotation VI fertilized	639 acres	-	5,639.81	-5,639.81
	Steer calves medium grain	236 head	38,210.52	22,415.28	15,795.24
	Twenty - two month plan	1 cow	172.56	40.26	132.30
	Sell oats	3,944 bus.	2,508.38	-	2,508.38
	Sell hay	315 tons	2,804.04	-	2,804.04
		Total	43,695.50	28,095.35	15,600.15
P_{27}	Rotation VII fertilized	639 acres	-	5,400.19	-5,400.19
	Steer calves medium grain	172 head	27,848.35	16,336.56	11,511.79
	Twenty - two month plan	20 cows	3,451.26	805.16	2,646.10
	Sell oats	3,081 bus.	1,959.52	-	1,959.52
	Sell hay	575 tons	5,184.20	-	5,184.20
		Total	38,443.33	22,541.91	15,901.42
P_{28}	Rotation VIII fertilized	639 acres	-	6,064.11	-6,064.11
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	211 tons	1,902.38	-	1,902.38
		Total	44,852.22	28,859.31	15,992.91

(continued)

TABLE X (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{29}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	257 bus.	163.45	-	163.45
	Sell hay	500 tons	4,508.00	-	4,508.00
		Total	45,146.49	28,591.57	16,554.92
P_{30}	Rotation VIII fertilized	639 acres	-	6,064.11	-6,064.11
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	2,098 bus.	3,409.25	-	3,409.25
	Sell oats	1,073 bus.	682.43	-	682.43
	Sell hay	211 tons	1,902.38	-	1,902.38
		Total	44,852.22	28,859.31	15,992.91
P_{31}	Rotation VIII unfertilized	639 acres	-	4,117.08	-4,117.08
	Steer calves medium grain	227 head	36,753.34	21,560.46	15,192.88
	Sell wheat	1,189 bus.	1,932.12	-	1,932.12
	Sell hay	143 tons	1,289.29	-	1,289.29
		Total	39,974.75	25,677.54	14,297.21

TABLE XI

RESOURCES AVAILABLE, USED, AND LEFT OVER

PROGRAMS P_{21} TO P_{31}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{21}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	9,798	0
Used	639	396	345	684	262	0	6,844	0	0	0
Sold	-	-	-	-	-	-	-	6,614	9,798	0
Left over	0	472	650	466	1,982	6,000	31,156	0	0	0
P_{22}										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	6,124	0
Used	639	371	383	626	256	0	6,465	0	0	0
Sold	-	-	-	-	-	-	-	8,267	6,124	0
Left over	0	497	612	524	1,988	6,000	31,535	0	0	0
P_{23}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	18,165	458
Used	639	344	326	613	2,219	6,000	29,578	4,516	3,826	223
Sold	-	-	-	-	-	-	-	995	4,339	235
Left over	0	524	669	537	25	0	8,422	0	0	0
P_{24}										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	3,062	343
Used	639	375	523	613	2,162	6,000	23,164	3,518	3,062	296
Sold	-	-	-	-	-	-	-	4,749	0	47
Left over	0	493	472	537	82	0	14,836	0	0	0

(continued)

TABLE XI (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{25}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	4,899	549
Used	639	305	328	556	2,200	6,000	29,265	4,516	3,826	223
Sold	-	-	-	-	-	-	-	2,098	1,073	326
Left over	0	563	667	594	44	0	8,735	0	0	0
P_{26}										
Available	639	868	995	1,150	2,244	6,000	38,000	4,453	7,721	543
Used	639	276	351	445	2,183	6,000	28,067	4,453	3,777	228
Sold	-	-	-	-	-	-	-	0	3,944	315
Left over	0	592	644	705	61	0	9,933	0	0	0
P_{27}										
Available	639	868	995	1,150	2,244	6,000	38,000	3,562	6,177	869
Used	639	252	388	444	2,076	6,000	22,592	3,562	3,096	294
Sold	-	-	-	-	-	-	-	0	3,081	575
Left over	0	616	607	706	168	0	15,408	0	0	0
P_{28}										
Available	639	858	995	1,150	2,244	6,000	38,000	6,614	4,899	435
Used	639	318	385	530	2,212	6,000	28,861	4,516	3,826	224
Sold	-	-	-	-	-	-	-	2,098	1,073	211
Left over	0	550	610	620	32	0	9,139	0	0	0
P_{29}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	261	300	466	2,168	6,000	28,594	4,516	3,826	224
Sold	-	-	-	-	-	-	-	995	257	500
Left over	0	607	695	684	76	0	9,406	0	0	0

(continued)

TABLE XI (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{30}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	4,899	435
Used	639	318	385	530	2,212	6,000	28,862	4,516	3,826	224
Sold	-	-	-	-	-	-	-	2,098	1,073	211
Left over	0	550	610	620	32	0	9,138	0	0	0
P_{31}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,463	3,621	351
Used	639	317	375	530	2,104	5,675	25,694	4,274	3,621	208
Sold	-	-	-	-	-	-	-	1,189	0	143
Left over	0	551	620	620	140	325	12,306	0	0	0

TABLE XII

COMPARISON OF RETURNS FROM FERTILIZED AND UNFERTILIZED ROTATIONS

Rotation	Amount Spent on Fertilizer	Increase in Return Due to Fertilizer	
	$	$[a]	%[b]
I	2,125.95	1,370.04	13.5
II	1,922.75	1,430.33	13.2
III	2,416.70	1,270.12	8.1
IV	2,040.33	2,102.68	13.1
V	2,440.98	1,573.41	9.5
VI	1,698.46	1,558.74	10.0
VII	1,766.84	1,581.01	9.9
VIII	1,947.03	1,576.74	9.9
IX	1,964.28	1,955.02	11.8

[a] This refers to net return to fixed resources.

[b] This is the percentage increase over the return from the unfertilized rotation.

Fertilizer Use Under Present Situation

In this section the returns from fertilizer under the present enterprise restrictions were tested. As can be seen from Table X the return from rotation VIII fertilized (P_{30}) exceeds the return from rotation VIII unfertilized by $1,695.70. The farmer is well advised to use the fertilized rotation if he retains the present restrictions on enterprises considered.

III. A COMPARISON OF THE RETURNS FROM VARIOUS LIVESTOCK ENTERPRISES

In this section strategic livestock enterprises were allowed to compete with all rotations and all grain buying and selling activities. In this way the optimum farm plan given the livestock enterprises can be determined. It is to be noted that no hay selling activity is included in these programs. All hay produced must be used in the livestock enterprises or left idle.

The results of all the programs calculated for this section are presented in Tables XIII and XIV.

In program P_{32} all livestock enterprises were considered. The only livestock enterprise included in the final plan was 240 head of steer calves fed a medium grain ration. Rotation II fertilized was included at 223 acres and rotation IV fertilized at 416 acres. With this combination

TABLE XIII

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_{32} TO P_{45}

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{32}	Rotation II fertilized	223 acres	-	2,256.31	-2,256.31
	Rotation IV fertilized	416 acres	-	4,057.66	-4.057.66
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	3,751 bus.	6,095.38	-	6,095.38
	Sell oats	306 bus.	194.62	-	194.62
		Total	45,148.16	29,109.17	16,038.99
P_{33}	Rotation II fertilized	223 acres	-	2,256.31	-2,256.31
	Rotation IV fertilized	416 acres	-	4,057.66	-4,057.66
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	3,751 bus.	6,095.38	-	6,095.38
	Sell oats	306 bus.	194.62	-	194.62
		Total	45,148.16	29,109.17	16,038.99
P_{34}	Rotation IV fertilized	240 acres	-	2,340.96	-2,340.96
	Rotation V fertilized	284 acres	-	4,118.08	-4,118.08
	Twenty - two month plan	73 cows	12,997.10	2,938.83	9,658.27
	Sell wheat	6,098 bus.	9,909.25	-	9,909.25
	Sell oats	2,973 bus.	1,890.83	-	1,890.83
		Total	24,397.18	9,397.87	14,999.31

(continued)

TABLE XIII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{35}	Rotation II fertilized	387 acres	-	3,915.67	-3,915.67
	Rotation IV fertilized	252 acres	-	2,458.01	-2,458.01
	Steer calves heavy grain	240 head	38,860,56	22,795.20	16,065.36
	Sell wheat	2,615 bus.	4,249.38	-	4,249.38
	Sell oats	130 bus.	82.68	-	82.68
		Total	43,192.62	29,168.88	14,023.74
P_{36}	Rotation II fertilized	223 acres	-	2,256.31	-2,256.31
	Rotation IV fertilized	416 acres	-	4,057.66	-4,057.66
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	3,751 bus.	6,095.38	-	6,095.38
	Sell oats	306 bus.	194.62	-	194.62
		Total	45,148.16	29,109.17	16,038.99
P_{37}	Rotation II fertilized	480 acres	-	4,856.64	-4,856.64
	Rotation IV fertilized	159 acres	-	1,550.89	-1,550.89
	Yearl. steers heavy grain	158 head	31,900.04	23,467.74	8,432.30
	Sell wheat	4,707 bus.	7,648.88	-	7,648.88
	Sell oats	2,354 bus.	1,497.14	-	1,497.14
		Total	41,046.06	29,875.27	11,170.79
P_{38}	Rotation II fertilized	361 acres	-	3,652.60	-3,652.60
	Rotation IV fertilized	278 acres	-	2,711.61	-2,711.61
	Yearl.steers medium grain	158 head	31,990.04	23,368.20	8,621.84
	Sell wheat	5,551 bus.	9,020.38	-	9,020.38
	Sell oats	2,495 bus.	1,586.82	-	1,586.20
		Total	42,597.24	29,732.41	12,864.21
P_{39}	Rotation II fertilized	495 acres	-	5,008.41	-5,008.41
	Rotation IV fertilized	144 acres	-	1,404.58	-1,404.58
	2 yr.old steers heavy gr.	158 head	36,249.15	28,853.96	7,395.19
	Sell wheat	5,041 bus.	8,191.62	-	8,191.62
	Sell oats	2,844 bus.	1,808.78	-	1,808.78
		Total	46,249.55	35,266.95	10,982.60

(continued)

TABLE XIII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{40}	Rotation II fertilized	389 acres	-	3,935.90	-3,935.90
	Rotation IV fertilized	250 acres	-	2,438.50	-2,438.50
	2 yr.old steers med. gr.	158 head	36,249.15	28,771.80	7,477.35
	Sell wheat	5,783 bus.	9,397.38	-	9,397.38
	Sell oats	2,826 bus.	1,797.34	-	1,797.34
		Total	47,443.87	35,146.20	12,297.67
P_{41}	Rotation IV fertilized	559 acres	-	5,452.49	-5,452.49
	Rotation V fertilized	80 acres	-	825.68	- 825.68
	Finished calves heavy gr.	82 cows	11,381.76	2,908.87	8,472.89
	Sell wheat	6,359 bus.	10,333.38	-	10,333.38
	Sell oats	1,537 bus.	977.53	-	977.53
		Total	22,692.67	9,187.04	13,505.63
P_{42}	Rotation IV fertilized	491 acres	-	4,789.21	-4,789.21
	Rotation V fertilized	148 acres	-	1,527.51	-1,527.51
	Finished calves medium gr.	82 cows	11,381.76	2,868.77	8,512.99
	Sell wheat	6,462 bus.	10,500.75	-	10,500.75
	Sell oats	1,969 bus.	1,252.28	-	1,252.28
		Total	23,134.79	9,185.49	13,949.30
P_{43}	Rotation IV fertilized	355 acres	-	3,591.89	-3,591.89
	Rotation V fertilized	284 acres	-	2,931.16	-2,931.16
	Overwinter and fatten	82 cows	11,708.94	3,035.39	8,673.55
	Sell wheat	6,134 bus.	9,967.75	-	9,967.75
	Sell oats	2,164 bus.	1,376.30	-	1,376.30
		Total	23,053.99	9,558.44	13,494.55

(continued)

TABLE XIII (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{44}	Rotation IV fertilized	240 acres	-	2,340.96	-2,340.96
	Rotation V fertilized	399 acres	-	4,118.08	-4,118.08
	Twenty - two month plan	73 cows	12,597.10	2,938.83	9,658.27
	Sell wheat	6,098 bus.	9,909.25	-	9,909.25
	Sell oats	2,973 bus.	1,890.83	-	1,890.83
		Total	24,397.18	9,397.87	14,999.31
P_{45}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Sell wheat	5,511 bus.	8,955.38	-	8,955.38
	Sell oats	4,083 bus.	2,596.79	-	2,596.79
	Sell hay	724 tons	6,527.58	-	6,527.58
		Total	18,079.75	5,796.37	12,283.38

TABLE XIV

RESOURCES AVAILABLE, USED, AND LEFT OVER

PROGRAMS P_{32} TO P_{45}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.		$	bus.	bus.	tons
P_{32}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,130	224
Used	639	356	458	576	2,244	6,000		29,112	4,516	3,824	224
Sold	-	-	-	-	-	-		-	3,751	306	0
Left over	0	512	537	574	0	0		8,888	0	0	0
P_{33}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,130	224
Used	639	356	458	576	2,244	6,000		29,112	4,516	3,824	224
Sold	-	-	-	-	-	-		-	3,751	306	0
Left over	0	512	537	574	0	0		8,888	0	0	0
P_{34}											
Available	639	868	995	1,150	2,244	6,000		38,000	7,235	4,209	472
Used	639	465	691	768	1,991	6,000		9,305	1,137	1,236	472
Sold	-	-	-	-	-	-		-	6,098	2,973	0
Left over	0	403	304	382	241	0		28,695	0	0	0
P_{35}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,916	135
Used	639	343	429	596	2,092	6,000		29,187	5,652	4,786	135
Sold	-	-	-	-	-	-		-	2,615	130	0
Left over	0	525	566	554	152	0		8,813	0	0	0

(continued)

TABLE XIV (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.		$	bus.	bus.	tons
P_{36}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,130	224
Used	639	356	458	576	2,244	6,000		29,112	4,516	3,824	224
Sold	-	-	-	-	-	-		-	3,751	306	0
Left over	0	512	537	574	0	0		8,888	0	0	0
P_{37}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	5,362	85
Used	639	353	412	607	1,161	6,000		29,875	3,560	3,008	85
Sold	-	-	-	-	-	-		-	4,707	2,354	0
Left over	0	515	583	543	1,083	0		8,125	0	0	0
P_{38}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,792	149
Used	639	340	433	593	1,246	6,000		29,732	2,716	2,297	149
Sold	-	-	-	-	-	-		-	5,551	2,495	0
Left over	0	528	562	557	998	0		8,268	0	0	0
P_{39}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	5,434	77
Used	639	355	409	609	1,007	6,000		35,267	3,226	2,590	77
Sold	-	-	-	-	-	-		-	5,041	2,844	0
Left over	0	513	586	541	1,237	0		2,733	0	0	0
P_{40}											
Available	639	868	995	1,150	2,244	6,000		38,000	8,267	4,926	134
Used	639	343	428	596	1,079	6,000		35,146	2,484	2,100	134
Sold	-	-	-	-	-	-		-	5,783	2,826	0
Left over	0	525	567	554	1,165	0		2,854	0	0	0

(continued)

TABLE XIV (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Space	Cattle Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{41}										
Available	639	868	995	1,150	2,244	6,000	38,000	8,060	3,292	369
Used	639	456	545	637	1,815	6,000	9,176	1,701	1,755	369
Sold	-	-	-	-	-	-	-	6,359	1,537	0
Left over	0	412	450	513	429	0	28,824	0	0	0
P_{42}										
Available	639	868	995	1,150	2,244	6,000	38,000	7,884	3,487	391
Used	639	501	547	637	1,812	6,000	9,161	1,422	1,518	391
Sold	-	-	-	-	-	-	-	6,462	1,969	0
Left over	0	367	448	513	432	0	28,839	0	0	0
P_{43}										
Available	639	868	995	1,150	2,244	6,000	38,000	7,532	3,878	435
Used	639	493	710	735	1,831	6,000	9,378	1,398	1,714	435
Sold	-	-	-	-	-	-	-	6,134	2,164	0
Left over	0	375	285	415	413	0	28,622	0	0	0
P_{44}										
Available	639	868	995	1,150	2,244	6,000	38,000	7,235	4,209	472
Used	639	465	691	768	1,997	6,000	9,305	1,137	1,236	472
Sold	-	-	-	-	-	-	-	6,098	2,973	0
Left over	0	403	304	382	247	0	28,695	0	0	0
P_{45}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	230	166	466	147	0	5,796	0	0	0
Sold	-	-	-	-	-	-	-	5,511	4,083	724
Left over	0	638	829	684	2,097	6,000	32,204	0	0	0

of rotations all the land was just used up and just enough hay produced to supply the livestock enterprise. The excess wheat and oats were sold. The return realized was equal to $16,038.99.

In P_{33} the most profitable combination of cattle finishing enterprises was selected. The final plan determined by this program was exactly the same as that determined for P_{32}.

In program P_{34} the optimum combination of cow - finished calf enterprises was selected. The final plan included only one livestock enterprise - the twenty-two month plan at the 73 cow level. In addition rotation IV fertilized was included at 240 acres and rotation V fertilized at 399 acres. These rotations used all the land and supplied just enough hay for the livestock enterprise. The shift from cattle finishing to cow - finished calf enterprises involves a shift not only in the livestock enterprises but also in the rotation enterprises. Again the importance of a complete farm plan is pointed out.

In the optimum cattle finishing program rotations II and IV are included while in the optimum cow - finished calf program rotations IV and V are included. Rotation II produces no hay at all while 40 percent of the land in rotation V is devoted to hay production. The cow - finished calf enterprises are relatively high hay using enterprises and this accounts for the shift. The optimum farm organization,

when only cow-finished calf enterprises are considered, returns $14,999.31. This return is $1,039.68 below the return realized by the optimum livestock combination determined in P_{32}.

In each of the programs P_{35} to P_{40} only one cattle finishing enterprise is allowed to compete. In each program the final plan included the livestock enterprise at the maximum level allowed by the supply of cattle space. In each program rotations II fertilized and IV fertilized were included at levels that just used up all available land and just supplied enough hay for use in the livestock activities. All excess wheat and oats were sold. Again the importance of a complete farm plan is pointed out. It is not sufficient to select only the livestock enterprise to be used. It is necessary to select the combination of rotations that when combined with the given livestock enterprise results in the maximum return. In these programs the necessary hay is supplied by rotation IV fertilized and the remaining land devoted to rotation II fertilized which allows a maximum of grain to be sold.

In each of the programs P_{41} to P_{44} of this section only one cow - finished calf enterprise was allowed to compete. Again in each program the livestock enterprise was included at the maximum level allowed by the cattle space. In each of these programs rotations IV fertilized and V fertilized were included at levels such that all the land was used up

and just enough hay produced to feed the livestock. The excess wheat and oats were sold. In these programs the final plan selected combined the rotations such that the necessary hay was produced in such a way that the maximum return for the complete farm plan was realized. Again the importance of a complete farm plan is emphasized. The shift from rotation II used with the cattle finishing enterprises was made necessary because of the increased hay requirements of the cow-finished calf enterprises.

The return from each of the programs P_{35} to P_{44} and the amount by which the return is below that realized by the optimum livestock combination determined in P_{32} is presented in Table XV.

From Table XV it can be seen that the most profitable farm plan is realized when the steer calves are the only livestock enterprise considered. Substantial losses are suffered when other livestock enterprises are used as the base. It is interesting that the second most profitable livestock enterprise is the twenty-two month plan. This enterprise is a very high hay using enterprise while steer calves medium grain have a relatively low hay requirement. The steer calf medium grain enterprise does however use more hay than any of the other cattle finishing enterprises. Also, it can be seen that if the two steer calf enterprises are excluded the return from all the cow - finished calf enterprises exceeds the return from any of the cattle

TABLE XV

COMPARISON OF RETURNS FROM LIVESTOCK ENTERPRISES

Program	Livestock Enterprise Considered	Return	Amount Below the Optimum Livestock Plan
		$	$
P_{35}	Steer calves heavy grain	14,023.74	2,015.25
P_{36}	Steer calves medium grain	16,038.99	0
P_{37}	Yearling steers heavy grain	11,170.79	4,868.20
P_{38}	Yearling steers medium grain	12,864.21	3,174.78
P_{39}	Two year old steers heavy grain	10,982.62	5,056.39
P_{40}	Two year old steers medium grain	12,297.67	3,741.32
P_{41}	Finished calves heavy grain	13,505.63	2,533.36
P_{42}	Finished calves medium grain	13,949.30	2,089.69
P_{43}	Overwinter and fatten	13,494.55	2,544.44
P_{44}	Twenty-two month plan	14,999.31	1,039.68

finishing enterprises. This seems to indicate that the final plans developed when higher hay using livestock enterprises are used as a base are more profitable.

In each program the most profitable complete farm plan is combined with the given livestock enterprise. The choice of the base livestock enterprise is still important however as indicated by the substantial differences in return realized by the different programs.

In the final program calculated for this section, P_{45}, no livestock activities were allowed to enter the final plan. The results of this program are given in Table XIII and Table XIV. The most profitable rotation when all the crop production must be sold is rotation IX fertilized. This rotation enters the final plan of this program at 639 acres. The sale of the crop production results in a return of $12,283.38. This is $3,755.61 below that realized by the optimum livestock plan. Thus the exclusion of livestock enterprises has a substantial effect on the return realized.

IV. VARIABLE RESOURCES

Capital

In this section the five programs P_{46} to P_{50} were used. In P_{46} capital was held at $10,000. In each successive program the capital restriction was raised $5,000 until in P_{50} it was entered at $30,000. At this level capital no

longer was a limiting factor so that further increases in capital could not change the final plan. The results of these programs are presented in Tables XVI and XVII.

In each of the first four programs in which capital is limiting both steer calves medium grain and the twenty-two month plan are included in the final plan. As the capital supply becomes larger the number of steer calves included increases and the number of cows included decreases. This is to be expected as the steer calf enterprise uses much more capital than the twenty-two month plan. At each capital level a different combination of rotation enterprises is considered but no pattern is established. As capital is not limiting in P_{50} the final plan determined is the overall optimum. With each increase in capital a complete reorganization of the farm plan is necessary. Unless this is done the best use is not made of the capital available.

The returns realized at each capital level and the returns to the additional capital are presented in Table XVIII. As can be seen from the table no pattern of increasing, decreasing or constant returns to additional capital is established. This is to be expected when only five capital levels are considered. The increase to additional capital in dollar terms does not appear too significant. When this increas is taken as a percent of the additional capital as in Table XVIII it appears more significant. If the additional capital can be acquired at a cost less than

TABLE XVI

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_{46} TO P_{51}

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{46}	Rotation V fertilized	639 acres	-	6,595.12	-6,595.12
	Twenty - two month plan	70 cows	12,079.41	2,818.06	9,261.35
	Steer calves medium grain	7 head	1,133.36	664.86	468.50
	Sell wheat	5,374 bus.	8,732.75	-	8,732.75
	Sell oats	3,582 bus.	2,278.15	-	2,278.15
	Sell hay	85 tons	766.36	-	766.36
		Total	24,990.03	10,078.04	14,911.99
P_{47}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	76 head	12,305.08	7,218.48	5,086.60
	Twenty - two month plan	50 cows	8,628.15	2,012.90	6,615.25
	Sell wheat	3,308 bus.	5,375.50	-	5,375.50
	Sell oats	2,027 bus.	1,289.17	-	1,289.17
	Sell hay	331 tons	2,984.30	-	2,984.30
		Total	30,582.20	15,027.75	15,554.45
P_{48}	Rotation IV fertilized	639 acres	-	6,232.81	-6,232.81
	Steer calves medium grain	131 head	21,210.08	12,442.38	8,767.70
	Twenty - two month plan	33 cows	5,694.58	1,328.51	4,366.07
	Sell wheat	5,287 bus.	8,591.38	-	8,591.38
	Sell oats	412 bus.	262.03	-	262.03
	Sell hay	7 tons	63.11	-	63.11
		Total	35,821.18	20,003.70	15,817.48

(continued)

TABLE XVI (continued)

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{49}	Rotation IV fertilized	480 acres	-	4,681.92	-4,681.92
	Rotation IX fertilized	159 acres	-	1,442.29	-1,442.29
	Twenty - two month plan	14 cows	2,415.88	563.61	1,852.27
	Steer calves medium grain	193 head	31,248.44	18,331.14	12,917.30
	Sell wheat	3,734 bus.	6,067.75	-	6,067.75
	Sell hay	165 tons	1,487.64	-	1,487.64
		Total	41,219.71	25,018.96	16,200.75
P_{50}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	257 bus.	163.45	-	163.45
	Sell hay	500 tons	4,508.00	-	4,508.00
		Total	45,146.49	28,591.57	16,554.92
P_{51}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	170 head	27,524.53	16,146.60	11,377.93
	Sell wheat	2,318 bus.	3,766.75	-	3,766.75
	Sell oats	1,377 bus.	875.77	-	875.77
	Sell hay	566 tons	5,103.06	-	5.103.06
		Total	37,270.11	21,942.97	15,327.14

TABLE XVII

RESOURCES AVAILABLE, USED AND LEFT OVER

PROGRAMS P_{46} TO P_{51}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{46}										
Available	639	868	995	1,150	2,244	6,000	10,000	6,614	4,899	550
Used	639	450	644	764	1,994	6,000	10,000	1,240	1,317	465
Sold	-	-	-	-	-	-	-	5,374	3,583	85
Left over	0	418	351	386	250	0	0	0	0	0
P_{47}										
Available	639	868	995	1,150	2,244	6,000	15,000	5,511	4,083	724
Used	639	363	523	613	2,042	6,000	15,000	2,203	2,056	393
Sold	-	-	-	-	-	-	-	3,308	2,027	331
Left over	0	505	472	537	202	0	0	0	0	0
P_{48}										
Available	639	868	995	1,150	2,244	6,000	20,000	8,267	3,062	343
Used	639	399	575	647	2,129	6,000	20,000	2,980	2,650	336
Sold	-	-	-	-	-	-	-	5,287	412	7
Left over	0	469	420	503	115	0	0	0	0	0
P_{49}										
Available	639	868	995	1,150	2,244	6,000	25,000	7,581	3,316	438
Used	639	343	459	571	2,169	6,000	25,000	3,847	3,316	273
Sold	-	-	-	-	-	-	-	3,734	0	165
Left over	0	525	536	579	75	0	0	0	0	0

(continued)

TABLE XVII (continued)

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{50}										
Available	639	868	995	1,150	2,244	6,000	30,000	5,511	4,083	724
Used	639	261	300	466	2,168	6,000	28,594	4,516	3,826	224
Sold	-	-	-	-	-	-	-	995	257	500
Left over	0	607	695	684	76	0	1,406	0	0	0
P_{51}										
Available	639	868	995	1,150	1,576	6,000	38,000	5,511	4,083	724
Used	639	252	261	466	1,576	4,250	21,945	3,193	2,706	158
Sold	-	-	-	-	-	-	-	2,318	1,377	566
Left over	0	616	734	684	0	1,750	16,055	0	0	0

TABLE XVIII

RETURN AT VARIOUS CAPITAL LEVELS AND

RETURN TO ADDITIONAL CAPITAL

Program	Capital Level	Return	Return to Additional Capital	
	$	$	$	%
P_{46}	10,000	14,911.99	-	-
P_{47}	15,000	15,554.45	642.46	12.8
P_{48}	20,000	15,817.48	263.03	5.3
P_{49}	25,000	16,200.75	383.27	7.8
P_{50}	30,000	16,554.92	354.17[a]	9.6[a]

[a] This is the return to $3,704- the additional amount of capital used.

the realized return it is to the farmer's advanatage to increase the amount of capital used.

Winter Labour

For this section only one program was calculated the results of which are presented in Tables XVI and XVII. In this program (P_{51}) the available winter labour was reduced from 2,244 hours to 1,576 hours. In this program the steer calves medium grain entered at 170 head and rotation IX fertilized at 639 acres. The excess wheat, oats and hay were sold. The major difference between this plan and the optimum plan is that the steer calf enterprise was restricted by the available winter labour. The return from this program was $1,227.78 below the return for the optimum plan. The returns per hour of the additional 668 hours of labour was $1.93. If the farmer can supply this additional 668 hours of labour for less than $1.93 per hour it is to his advantage to do so. This means that if he can either purchase labour for less than $1.93 or supply it himself at an opportunity cost of less than $1.93 it will result in increased returns.

V. EFFECT OF EXCLUSION OF THE HAY SELLING ACTIVITY

For this section four programs (P_{52} to P_{55}) were calculated. The results of the programs are presented in Tables

XIX and XX.

In the first program (P_{52}) the overall optimum with the hay selling activity excluded was determined. In this first plan 240 head of steer calves medium grain were included. Two rotations were included - rotation II fertilized and rotation IV fertilized. These rotations were included at levels which just used up the land and just supplied enough hay for the livestock. The return was equal to $16,038.99, $515.93 below the overall optimum.

In each of the other three programs only one crop rotation was allowed to compete. All livestock and grain selling and buying activities were included. In P_{53} and P_{54} which considered rotation IV fertilized and rotation VIII fertilized respectively, both steer calves medium grain and the twenty-two month plan were included in the final plan. These two enterprises were included at levels which just used up all the hay produced and all the cattle space available. In both programs the rotations used all the available land.

In P_{55} rotation IX fertilized was considered. The rotation entered the final plan at 639 acres. There was only one livestock enterprise included in the final plan - the twenty-two month cow - finished calf enterprise. This enterprise was limited by the covered cattle space. Even though the highest hay using livestock enterprise was included in the final plan, 252 tons of hay were left idle

TABLE XIX

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_{52} TO P_{55}

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{52}	Rotation II fertilized	223 acres	-	2,256.31	-2,256.31
	Rotation IV fertilized	416 acres	-	4,057.66	-4,057.66
	Steer calves medium grain	240 head	38,858.16	22,795.20	16,062.96
	Sell wheat	3,751 bus.	6,095.38	-	6,095.38
	Sell oats	306 bus.	194.62	-	194.62
		Total	45,148.16	29,109.17	16,038.99
P_{53}	Rotation IV fertilized	639 acres	-	6,232.81	-6,232.81
	Steer calves medium grain	124 head	20,076.72	11,777.52	8,299.20
	Twenty - two month plan	35 cows	6,039.70	1,409.03	4,630.67
	Sell wheat	5,381 bus.	8,744.12	-	8,744.12
	Sell oats	484 bus.	307.82	-	307.82
		Total	35,168.36	19,419.36	15,749.00
P_{54}	Rotation VIII fertilized	639 acres	-	6,064.11	-6,064.11
	Steer calves medium grain	36 head	5,828.72	3,419.28	2,409.44
	Twenty - two month plan	62 cows	10,698.91	2,496.00	8,202.91
	Sell wheat	4,966 bus.	8,069.75	-	8,069.75
	Sell oats	3,269 bus.	2,079.08	-	2,079.08
		Total	26,676.46	11,979.39	14,697.07
P_{55}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Twenty - two month plan	73 cows	12,597.10	2,938.83	9,658.27
	Sell wheat	4,376 bus.	7,111.00	-	7,111.00
	Sell oats	2,845 bus.	1,809.42	-	1,809.42
		Total	21,517.52	8,735.20	12,782.32

TABLE XX

RESOURCES AVAILABLE, USED AND LEFT OVER

PROGRAMS P_{52} TO P_{55}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{52}										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	4,130	224
Used	639	356	458	576	2,244	6,000	29,112	4,516	3,824	224
Sold	-	-	-	-	-	-	-	3,751	306	0
Left over	0	512	537	574	0	0	8,888	0	0	0
P_{53}										
Available	639	868	995	1,150	2,244	6,000	38,000	8,267	3,062	343
Used	639	403	584	653	2,123	6,000	19,446	2,886	2,578	343
Sold	-	-	-	-	-	-	-	5,381	484	0
Left over	0	465	411	495	121	0	18,554	0	0	0
P_{54}										
Available	639	868	995	1,150	2,244	6,000	38,000	6,614	4,899	435
Used	639	445	661	713	2,032	6,000	12,001	1,648	1,630	435
Sold	-	-	-	-	-	-	-	4,966	3,269	0
Left over	0	423	334	437	212	0	25,999	0	0	0
P_{55}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	410	777	681	1,955	6,000	8,722	1,135	1,238	472
Sold	-	-	-	-	-	-	-	4,376	2,845	0
Left over	0	458	218	469	289	0	29,278	0	0	252

in the program.

In Table XXI the returns realized from each of these programs are presented and compared with previous programs which were exactly similar except for the exclusion of the hay selling activity. From the table it can be seen that with some rotations the loss of the hay market can be overcome through adjustment of the livestock enterprises. This is the case with rotation IV. In others such as rotation IX which produces a large amount of hay this cannot be done and substantial losses are incurred. In P_{52} the adjustment was made through changes in the rotations rather than in the livestock enterprises. This points out the importance of considering all possible adjustments to changing conditions. If the only adjustments considered were those that could be made in the livestock enterprises substantial losses could be suffered. This is especially the case with the overall optimum which contains 639 acres of rotation IX. Other considerations will also enter into this decision. The farmer would have to decide whether or not the loss of hay market was temporary or permanent. If it was only temporary it might not be to his advantage to introduce a new rotation or even to readjust the livestock enterprises. He might find it desirable to let the hay remain unused.

TABLE XXI

COMPARISON OF RETURNS FROM PROGRAMS INCLUDING THE HAY SELLING ACTIVITY WITH THOSE IN WHICH THE HAY SELLING ACTIVITY IS EXCLUDED

Program	Rotation Considered	Return		Difference
		Including Hay Selling	Excluding Hay Selling	
		$	$	
P_{53}	IV fertilized	15,997.16	15,749.00	248.16
P_{54}	VIII fertilized	15,901.42	14,697.07	1,204.35
P_{55}	IX fertilized	16,554.92	12,782.32	3,772.60

VI. EFFECT OF PRICE CHANGES

For this section two programs were computed the results of which are presented in Tables XXII and XXIII. In P_{56} the price of purchased cattle for the cattle finishing enterprises was raised 5 percent and in P_{57} this price was raised 10 percent. This decreases the return and increases the capital requirements of all the cattle finishing enterprises.

In P_{56} the only change from the overall optimum is a decrease of $941.99 in the return and an increase of $940 in the amount of capital used. The steer calves medium grain are still included at the 240 head level.

In P_{57} the steer calves medium grain are completely replaced by the twenty-two month plan. Rotation IX fertilized still remains in the final plan at 639 acres. This results in a decrease in return of $1,500.57 from that realized with the overall optimum plan. Retaining the steer calves would reduce the return another $383.41.

If the price of purchased cattle increases by 10 percent the farmer who has included cattle finishing enterprises in his farm plan must, in order to maximize returns, replace the cattle finishing enterprises with a twenty-two month cow - finished calf enterprise. If a farmer is considering which livestock enterprise to include in his production plan he must decide whether or not this 10 percent price increase

TABLE XXII

FINAL PLAN AND FINANCIAL SUMMARY FOR

PROGRAMS P_{56} AND P_{57}

Program	Enterprises Included in the Final Plan	Enterprise Level	Receipts	Expenses	Return
			$	$	$
P_{56}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Steer calves medium grain	240 head	38,858.16	23,737.20	15,120.96
	Sell wheat	995 bus.	1,616.88	-	1,616.88
	Sell oats	257 bus.	163.45	-	163.45
	Sell hay	500 tons	4,508.00	-	4,508.00
		Total	45,146.49	29,533.57	15,612.92
P_{57}	Rotation IX fertilized	639 acres	-	5,796.37	-5,796.37
	Twenty - two month plan	73 cows	12,597.10	2,938.83	9,658.27
	Sell wheat	4,376 bus.	7,111.00	-	7,111.00
	Sell oats	2,845 bus.	1,809.42	-	1,809.42
	Sell hay	252 tons	2,272.03	-	2,272.03
		Total	23,789.55	8,735.20	15,054.35

TABLE XXIII

RESOURCES AVAILABLE, USED AND LEFT OVER

PROGRAMS P_{56} AND P_{57}

Program	Resource									
	Land	Spring Labour	Summer Labour	Fall Labour	Winter Labour	Covered Cattle Space	Capital	Wheat	Oats	Hay
	acres	hrs.	hrs.	hrs.	hrs.	sq. ft.	$	bus.	bus.	tons
P_{56}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	261	300	466	2,168	6,000	29,534	4,416	3,826	224
Sold	-	-	-	-	-	-	-	995	257	500
Left over	0	607	695	684	76	0	8,466	0	0	0
P_{57}										
Available	639	868	995	1,150	2,244	6,000	38,000	5,511	4,083	724
Used	639	410	777	681	1,955	6,000	8,722	1,135	1,238	472
Sold	-	-	-	-	-	-	-	4,376	2,845	252
Left over	0	458	218	469	289	0	29,378	0	0	0

is likely to occur in the future. If he feels it will he is better off to include a twenty-two month cow - finished calf enterprise which under the conditions assumed as normal in this study returns less than a plan which includes steer calves medium grain.

Since the cattle finishing enterprises that were considered in this study are excluded at this price level, further increases in the price of these enterprises could have no ef effect on the final plan.

CHAPTER V

SUMMARY AND CONCLUSIONS

The central objective of this thesis was to study the problems of farm organization on a particular soil type of Manitoba - Red River Clay. The problem facing farmers is the selection of the farm production plan which will maximize return to the fixed resources. This is the point of equilibrium of the firm developed in marginal economic analysis. The selection of this production plan is made very difficult by the many changes that have occured in the agricultural industry. This study was designed to show how improved farm organization can increase returns and also what types of farm organization are best suited to Red River Clay soil.

Six specific problems of farm organization were selected for consideration in this study. The effect on income and farm organization of the following were considered:

1) The level at which grass and legumes are included in the crop rotation.

2) Fertilizer use at rates recommended by agronomists as compared with no fertilizer use.

3) The livestock enterprises included in the farm plan.

4) Variation in the levels at which "key" resources are made available. The resources considered in this study were operating capital and winter labour.

5) The loss of the hay market. That is, if all hay produced must either be fed to the livestock or left unused.

6) Variation in the prices of "key" enterprises. In this study only one price change was considered. This was a price increase for the cattle purchased for the cattle finishing enterprises.

The empirical tool used in the study was linear programming. Linear programming is a tool which allows the determination of the production plan which will maximize income given assumptions concerning the resources available, enterprises to be considered and the input - output coefficients for these enterprises.

In this study the base farm on which the empirical work was done was an existing farm. This farm included approximately one section of crop land and has as its principle livestock enterprise a cattle finishing enterprise. It was determined in the study that the organization which resulted in maximum returns for this farm included 240 head of steer calves fed a medium grain ration and 639 acres of a wheat - wheat - oats - hay - hay - hay rotation. These two enterprises combined with grain and hay selling activities resulted in a return to the fixed resources of $16,554.92. This is $562.01 more than could be realized if the present

rotation was retained.

One important conclusion that can be drawn from the empirical evidence is that the farm plan considered must be a complete farm plan. Farm organization consists of an integration of crop rotations, livestock enterprises and grain and hay buying and selling activities such that maximum return is realized. If a change occurs in the conditions facing one sector of the farm business it also affects this combination and thus the other sectors of the farm business. This principle must be recognized in order that the optimum farm organization can be achieved. The effect of a change in one sector on the complete farm organization must be determined and recognized.

The empirical evidence also points out that the choice of farm organization can have a substantial effect on the return received by the farm business. If limitations are placed on the enterprises allowed to enter the final plan the return realized can be substantially reduced.

Effect on Income and Farm Organization of the Level at Which Grass and Legumes are Included in the Crop Rotation

It was discovered that where the crop rotation used included no hay production return was substantially reduced. This was because none of the livestock enterprises considered in the study could be included in the final plan. When rotations were included which allowed the cattle space to be

fully utilized returns were greatly increased. The level of income received from the final plan when different rotations were considered did not vary too much as long as the cattle space was used up. Differences in return which did arise could not be attributed to the level of forage included in the rotation. They could be attributed to limitations placed on the livestock enterprises by feed restrictions. After choosing a rotation which is to be used the farmer must be prepared to combine with this rotation the combination of livestock enterprises which will maximize the return. In the final plans developed for this study this was done. Simply choosing the rotation which will maximize returns is not enough, the complete farm plan associated with the rotation must be introduced.

Effect on Income and Farm Organization of Fertilizer Use at Rates Recommended by Agronomists as Compared with No Fertilizer Use

In each case the returns resulting from the optimum farm plan were higher when the rotation being considered was fertilized at the recommended rates than when it was not fertilized. The farmer who is faced with a choice between not fertilizing and fertilizing at the recommended rates can be advised to fertilize. It cannot be concluded from this study that the recommended rates are the optimum rates of fertilizer application. Other rates not considered in this

study could result in even higher returns.

Effect on Income and Farm Organization of the Livestock Enterprises Included in the Final Plan

The most profitable farm organization developed in this section included steer calves fed a medium grain ration as the only livestock enterprise. The next most profitable was the twenty-two month cow - finished calf enterprise. In the steer calf enterprise a relatively high grain ration was used while the twenty-two month plan is a high hay using enterprise. If the two steer calf enterprises are excluded all the cow - finished calf enterprises result in a greater return than any of the other cattle finishing enterprises. Unless the farmer is able to acquire steer calves for his cattle finishing enterprise he may be advised to replace it with a cow - finished calf enterprise. The simple selection of the most profitable livestock enterprise does not assure the farmer of achieving the maximum return. He must be prepared to develop the complete farm organization which will assure this return as was done in the programs calculated for this study.

It was shown in the study that the return was substantially reduced when no livestock enterprises were included in the final plan. It thus appears to be to the farmers advantage to market his crop production through livestock rather than to sell it directly.

Effect on Income and Farm Organization of Varying "Key" Resources

Capital. The empirical evidence shows that substantial returns to additional capital can be realized as long as capital is a limiting factor. However in order to receive these returns a farmer must reorganize his farm business such that maximum return will be realized from the additional capital. Reorganization of the entire farm business must accompany each increase in the capital available.

Winter Labour. The decrease of the available winter labour substantially reduced the return. The reorganization of the farm business is not so complete in this case as winter labour is used only for the livestock enterprises. As a result the only change is a reduction in the level at which steer calves were included in the final plan.

Effect on Income and Farm Organization of the Loss of the Hay Market

The empirical evidence shows that the loss of the hay market need not reduce the return provided the proper reorganization of the farm business is carried out. The overall optimum plan determined without the inclusion of the hay selling activity returns only slightly less than the overall optimum including the hay selling activity. This reorganization requires a change in both the livestock and

rotation enterprises included. A temporary loss of hay market may not allow this complete a reorganization. Three programs were calculated which did not allow the rotation to be changed. In this case substantial losses were suffered with some rotations even though the livestock enterprises were adjusted. With other rotations only small losses were suffered. This is then another factor that should be taken into consideration by the farmer when choosing the crop rotation to be used.

Effect on Income and Farm Organization of Price Changes in "Key" Enterprises

In this study only the price of cattle purchased for cattle finishing enterprises was changed. The empirical evidence shows that a 5 percent increase in this price would have no effect on the optimum production plan other than a decrease in return. A 10 percent increase changes the nature of the entire farm organization. Farmers, in order to realize maximum return, must be prepared to make these necessary changes in farm organization as changes in price conditions occur. The farmer must also attempt to foresee what price changes will occur in the future as in agriculture it is necessary to develop a production plan in advance of the time when it will be implemented.

RECOMMENDATIONS FOR FURTHER STUDY

In this study only one soil type was considered, Red River Clay. Similar studies done on other soil types would assist farmers on these soil types with problems in farm organization.

In this present study only one type of livestock production is considered. Future studies done on Red River Clay and other soil types should consider a wider variety of livestock enterprises.

In the section of this thesis devoted to a study of fertilizer use only two levels of fertilizer application were considered, the zero level and the recommended rates. Further study involving a greater range of application rates is necessary to determine the most profitable rate of fertilizer application.

Further study could also be carried out on the effect of varying the level of "key" resources. More resources could be allowed to enter at different levels and the number of levels considered increased.

In this study single valued expectations were assumed for all input - output coefficients and prices. As pointed out earlier this assumption is not completely valid. Study on the effects of risk and uncertainty on farm organization is also required.

APPENDIX

APPENDIX

TABLE I

INPUT - OUTPUT COEFFICIENTS

Resource	Requirements				
	Rotation I Fertilized	Rotation I Unfertilized	Rotation II Fertilized	Rotation II Unfertilized	Rotation III Fertilized
Land (acres)	1.000	1.000	1.000	1.000	1.000
Spring labour (hrs.)	0.620	0.620	0.580	0.580	0.490
Summer labour (hrs.)	0.540	0.540	0.600	0.600	0.730
Fall labour (hrs.)	1.070	1.070	0.980	0.980	0.960
Winter labour (hrs.)	0.410	0.410	0.400	0.400	0.310
Covered cattle space (sq. ft.)	0.	0.	0.	0.	0.
Capital ($)	10.711	7.384	10.118	7.109	10.611
Wheat (lbs.)	-621.000	-513.000	-776.250	-641.250	-517.500
Oats (lbs.)	-521.333	-385.333	-325.833	-240.833	-434.444
Hay (lbs.)	0.	0.	0.	0.	-1,433.333
Net price ($)	-10.711	-7.384	-10.118	-7.109	-10.611

(continued)

Note: Negative coefficients indicate production rather than use.

TABLE I (continued)

Resource	Requirements				
	Rotation III Unfertilized	Rotation IV Fertilized	Rotation IV Unfertilized	Rotation V Fertilized	Rotation V Unfertilized
Land (acres)	1.000	1.000	1.000	1.000	1.000
Spring labour (hrs.)	0.490	0.470	0.470	0.430	0.430
Summer labour (hrs.)	0.650	0.780	0.720	0.820	0.730
Fall labour (hrs.)	0.960	0.860	0.860	0.870	0.870
Winter labour (hrs.)	0.310	0.320	0.320	0.280	0.280
Covered cattle space (sq. ft.)	0	0	0	0	0
Capital ($)	6.829	9.754	6.561	10.121	6.501
Wheat (lbs.)	-427.500	-776.250	-641.250	-621.000	-513.000
Oats (lbs.)	-321.111	-162.917	-120.417	-260.667	-192.667
Hay (lbs.)	-1,166.667	-1,075.000	-875.000	-1,720.000	-1,400.000
Net price ($)	-6.829	-9.754	-6.561	-10.321	-6.501

(continued)

TABLE I (continued)

Resource	Requirements				
	Rotation VI Fertilized	Rotation VI Unfertilized	Rotation VII Fertilized	Rotation VII Unfertilized	Rotation VIII Fertilized
Land (acres)	1.000	1.000	1.000	1.000	1.000
Spring labour (hrs.)	0.380	0.380	0.280	0.280	0.450
Summer labour (hrs.)	0.840	0.930	1.070	0.910	0.800
Fall labour (hrs.)	0.690	0.690	0.600	0.600	0.830
Winter labour (hrs.)	0.260	0.260	0.180	0.180	0.300
Covered cattle space (sq. ft.)	0.	0.	0.	0.	0.
Capital ($)	8.826	6.168	8.451	5.686	9.490
Wheat (lbs.)	-418.125	-358.125	-334.500	-286.500	-621.000
Oats (lbs.)	-410.833	-325.833	-328.667	-260.667	-260.667
Hay (lbs.)	-1,700.000	-1,375.000	-2,720.000	-2,200.000	-1,360.000
Net price ($)	-8.826	-6.168	-8.451	-5.686	-9.490

(continued)

TABLE I (continued)

Resource	Requirements				
	Rotation VIII Unfertilized	Rotation IX Fertilized	Rotation IX Unfertilized	Steer Calves Heavy Grain	Steer Calves Medium Grain
Land (acres)	1.000	1.000	1.000	0	0
Spring labour (hrs.)	0.450	0.360	0.360	0	0.128
Summer labour (hrs.)	0.720	0.940	0.800	0	0
Fall labour (hrs.)	0.830	0.730	0.730	0	0
Winter labour (hrs.)	0.300	0.230	0.230	7.736	8.420
Covered cattle space (sq. ft.)	0	0	0	25.000	25.000
Capital ($)	6.433	9.017	5.977	94.980	94.990
Wheat (lbs.)	-513.000	-517.500	-427.500	1,413.000	1,129.000
Oats (lbs.)	-192.667	-217.223	-160.556	678.000	542.000
Hay (lbs.)	-1,100.000	-2,266.667	-1,833.333	1,129.000	1,862.000
Net price ($)	-6.443	-9.071	-5.977	66.939	66.929

(continued)

TABLE I (continued)

Resource	Requirements			
	Heifer Calves Heavy Grain	Heifer Calves Medium Grain	Yearling Steers Heavy Grain	Yearling Steers Medium Grain
Land (acres)	0	0	0	0
Spring labour (hrs.)	0	0	0	0
Summer labour (hrs.)	0	0	0	0
Fall labour (hrs.)	0	0	0	0
Winter labour (hrs.)	7.479	8.334	5.813	6.411
Covered cattle space (sq. ft.)	25.000	25.000	38.000	38.000
Capital ($)	74.680	74.220	148.530	147.900
Wheat (lbs.)	1,320.000	1,051.000	1,353.000	1,032.000
Oats (lbs.)	633.000	504.000	648.000	495.000
Hay (lbs.)	1,055.000	1,768.000	1,081.000	1,890.000
Net price ($)	59.420	59.880	53.369	53.999

(continued)

TABLE I (continued)

Resource	Requirements			
	Yearling Heifers Heavy Grain	Yearling Heifers Medium Grain	2 Year Steers Heavy Grain	2 Year Steers Medium Grain
Land (acres)	0	0	0	0
Spring labour (hrs.)	0	0	0	0
Summer labour (hrs.)	0	0	0	0
Fall labour (hrs.)	0	0	0	0
Winter labour (hrs.)	5.086	5.556	4.830	5.432
Covered cattle space (sq. ft.)	38.000	38.000	38.000	38.000
Capital ($)	118.130	117.540	182.620	182.100
Wheat (lbs.)	1,154.000	876.000	1,226.000	944.000
Oats (lbs.)	553.000	420.000	558.000	452.000
Hay (lbs.)	922.000	1,612.000	979.000	1,703.000
Net price ($)	48.154	48.744	46.805	47.325

(continued)

TABLE I (continued)

Resource	Requirements			
	Finished Calves Heavy Grain	Finished Calves Medium Grain	Overwinter and Fatten	22 Month Plan
Land (acres)	0	0	0	0
Spring labour (hrs.)	1.930	2.514	2.480	2.480
Summer labour (hrs.)	0.525	0.525	2.432	2.432
Fall labour (hrs.)	1.050	1.050	2.220	2.957
Winter labour (hrs.)	19.642	19.642	19.935	24.884
Covered cattle space (sq. ft.)	73.041	73.041	73.041	82.525
Capital ($)	35.474	34.985	37.017	40.258
Wheat (lbs.)	1,243.082	1,039.065	1,020.888	937.860
Oats (lbs.)	726.083	628.333	709.700	579.233
Hay (lbs.)	8,990.617	9,522.483	10,593.959	12,999.951
Net price ($)	103.328	103.817	105.775	132.305

(continued)

TABLE I (continued)

Resource	Requirements				
	Sell Wheat	Sell Oats	Sell Hay	Buy Wheat	Buy Oats
Land (acres)	0	0	0	0	0
Spring labour (hrs.)	0	0	0	0	0
Summer labour (hrs.)	0	0	0	0	0
Fall labour (hrs.)	0	0	0	0	0
Winter labour (hrs.)	0	0	0	0	0
Covered cattle space (sq. ft.)	0	0	0	0	0
Capital ($)	0	0	0	1.625	0.636
Wheat (lbs.)	60.000	0	0	-60.000	0
Oats (lbs.)	0	34.000	0	0	-34.000
Hay (lbs.)	0	0	2,000	0	0
Net price ($)	1.625	0.636	9.016	-1.625	-0.636

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