AN EXPERIMENT IN THE USE OF FARM PROGRAMMING BY FERTILIZER DEALERS AS A SERVICE TO FARMERS

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AN EXPERIMENT IN THE USE OF FARM PROGRAMMING BY

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Chapter I

Introduction

The modern farm manager is continuously seeking innovations and services which can increase net returns. Many farmers are trying to make the adjustments needed to maintain or increase farm net returns on a given acreage. The adjustments that are often needed to maximize net returns cannot readily be seen without an overall examination of the entire farm operation.

The use of fertilizer for increasing yields and profits is one approach that many Oklahoma producers of wheat and feed grain have selected to increase or maintain net return per acre. Fertilizer is an increasingly important factor of production. Farmers in Oklahoma have increased their usage of fertilizer from 144,000 tons in 1959 to 470,000 tons in 1967.[1]

Average plant nutrient content of all fertilizers also has increased. In 1960, the nutrient content averaged 31.9 percent while the 1966 nutrient content averaged 37.7 percent.[2] The increase in fertilizer usage and trend to higher analysis fertilizer indicates that farmers are realizing the profitability of fertilizer.

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[1] Tonnage Distribution of Fertilizer in Oklahoma Counties by Grade and Material, Annual Reports from 1959 through 1967, Oklahoma State Department of Agriculture.

[2] Annual Fertilizer Consumption Reports, Statistical Reporting Service, United States Department of Agriculture.

Most farmers know that the wise use of plant foods is a key management practice in getting more profitable yields per acre. Each farmer is trying to determine the amount of input that will maximize net returns to each enterprise.

In addition to having all practices for the cropping enterprises at the maximum net return point, it is important to determine what combination of these enterprises would maximize net returns. The correct combination of enterprises should give the highest net farm return, limited only by the restrictions relevant to the enterprises.

Use of Linear Programming

Frequently the farm manager does not fully analyze the different alternatives that are available for his particular farming situation. But, linear programming makes it possible to consider numerous farm input-output alternatives simultaneously. If linear programming can be made commercially feasible, who would provide this service. One answer could be the suppliers of farm inputs.

Numerous studies have shown that fertilizer dealers already provide guidance to farmers as to the kinds and amounts of fertilizer to use.[3] Furthermore, since fertilizer is one of the largest input expenses of grain producers, fertilizer dealers might offer a linear programming service. Dealers could then better serve their farmer customers by employing the programming technique to estimate fertilizer needs and provide an analysis of alternative farm activities. The

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[3]E. L. Baum, Earl O. Heady, John T. Pesek, Clifford G. Heldreth, Fertilizer Innovations and Resource Use, Iowa State University Press Ames, Iowa, 1957, pp. 125-240.

service could be designed to analyze the specific questions the farm manager has pertaining to his farm operation.

Difficulties of obtaining answers to questions of optimum input uses and product combinations for individual farms are great. The reason rests on farmers' inability to equate marginal value products with the marginal cost of resources. According to Heady, the farmers' inability results from these considerations: (1) lack of knowledge of the relevant input-output relationships and cost structures; (2) the uncertainty of future prices and yields; and (3) the existence of severe capital limitations.[4]

According to Swanson, the success of the formal solution of any linear programming model in guiding farmers in making adjustments depends on two evaluation processes: (1) the evaluation performed by the programmer when he selects the variables he believes to be relevant and fits them into a formal mathematical structure and (2) evaluation of the formal results by the farmer (and those who may help him) to adapt the results to bear on his specific problem.[5] The more specific the situation that a program contains the less discussion and evaluation of the optimum solutions is needed at the farm level. Of course, the latter assumes that the program considers enterprises relevant to the actual farm operation.

Linear programming is capable of producing optimal answers by selecting the most profitable technical combination from alternatives considered. However, the production possibilities may be under or

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[4] Earl O. Heady, Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1952, p. 115.

[5] Earl L. Swanson, "Programming Optimal Farm Plans," Farm Size and Output Research, Southern Cooperatives Series Bulletin No. 56, p. 57.

over estimated due to errors in judgment or a poor bookkeeping system on the enterprises considered. Therefore, good budgets are in fact the heart of a good programming method. Much caution and diligence must be used in constructing particular budgets to fit the farmer's enterprises.

Objectives

The objectives of this study are (1) to develop a farm programming technique that fertilizer dealers can use with their farmer customers, (2) to test the programming device on actual farm organizations with cooperating farmers and fertilizer dealers and (3) to involve the co-operating dealers in an educational program to increase their knowledge of the economics involved in organizing a farm.

The first objective will be met by developing a linear programming model that can represent the alternatives of a specific farm as closely as possible. Different government program choices and various levels and combinations of inputs and products will compose the alternatives associated with a specific farm. Different fertilizer rates associated with the respective yields comprises the alternatives derived from a single enterprise. Similarly, use of different ingredients for a feed ration can add several alternatives to feeding livestock.

Objective two will be fulfilled through a cooperative program with farmers and fertilizer dealers in North Central Oklahoma. Together, the dealer and farmer can develop budgets for the enterprises that will be considered in the computer program. The various activities associated with each enterprise can then be determined. Application of the linear programming technique will determine the optimum farm organization to maximize net returns to land, labor, management and other fixed resources for the next crop year. Involvement of the dealer in the application of the technique and in a workshop contribute to fulfilling the third objective.

The third objective was designed to discover the type of problems the farm programming service could solve. Also, it was designed to present the economic and agronomic solutions the service could not solve.

Thesis Organization

Chapter II presents the theoretical concepts and the general form of the models applied in the thesis. Chapter III describes the dealer and farmer involvement, development of the linear programming procedure, the experimental results, and the actual farm situations involved in the experiment. Chapter IV discusses and explains a linear programming model for minimum cost fertilizer blending. Chapter V summarizes the previous three chapters, draws conclusions and discusses the need for further study.

Chapter II

ALTERNATIVE ANALYTICAL TECHNIQUES

Relevant economic theory and techniques for use in investigating a particular farm situation are briefly discussed in this chapter. Theory and techniques of special interest include guides for determining (1) the optimum combination of crop and livestock enterprises and (2) the optimum combination of inputs for a single enterprise. Each farm organization is distinctly different from another. Differences are due to varying capabilities and restrictions with which a farm operator is confronted. Thus, general rules are needed to examine any specific problem.

Marginal Analysis

The optimum combination of inputs for each enterprise and the most profitable combination of enterprises can be determined by the principles of production economics. The factor-product, factor-factor and product-product relationships are all involved when a farm manager confronts the decisions to be made on his particular farm organization.

The factor-product relationship employs the production function with relevant choice indicators such as prices of the factor and product. The factor-product or input-output relationship is used to determine the profit maximizing level of a variable resource used in the production of a product. The problem is one of intensity of production. The optimal intensity can be found by adding the variable factor to the fixed factors of production to the point where the returns obtained from the extra product produced (marginal value product) is equal to the cost of an additional unit of the variable factor (marginal factor cost). This condition is written in Equation (1):

$$MPP_f \cdot P_y = P_f \tag{1}$$

MPP_f is the marginal physical product of the variable resource f used in the production of product y, P_y is the price of product y and P_f is the price of the variable resource f. This relationship is used as a guide each time a single, variable input, for example nitrogen, contributes to the total output of a specific crop. Fertilizer is added until the revenue obtained from the extra product produced is equal to the cost of one additional unit of fertilizer.

Labor is added to the point where the revenue obtained from the extra product produced is equal to the cost of the additional unit of labor. When two or more factors of production are variable, the factors should be combined in that proportion which equates the marginal value product ($MPP_a \cdot P_y$) per dollar's worth of one factor used in the production of a product to the marginal value product per dollar's worth of the other factors used in the production of a product. The equilibrium condition is indicated in equation (2):

$$\frac{MPP_a \cdot P_y}{P_a} = \frac{MPP_b \cdot P_y}{P_b} = \ldots = \frac{MPP_n \cdot P_y}{P_n} = 1 + K \tag{2}$$

MPP_a is the marginal physical product of the variable resource a used in the production of product y, P_y is the price of product y and P_a is the price of the variable resource a. MPP_b is the marginal physical product of the second variable resource b used in the production of product y and P_b is the price of the resource b. Finally, MPP_n is the marginal physical product of the variable resource n used in the production of product y, and P_n is the price of the variable resource n used in the production of product y. With the ratios equal to one plus K, the variable resources will be used in the correct amounts and in the correct proportions for profit maximization. K is the cost of money expressed as the interest rate. A suitable example of this relationship is usage of labor, capital and land in the production of wheat. All three resources should be combined in that proportion which makes the value marginal product (VMP) per dollars worth of one used in the production of wheat equal to a dollars worth of all other inputs used in the production of wheat. Of course, no input can be exhausted before the most profitable proportion is obtained if the above condition is to hold.

The farm manager must make a decision as to what combination of enterprises to grow. The isorevenue line and the product transformation curve indicate graphically how the decision is made in Figure 1.

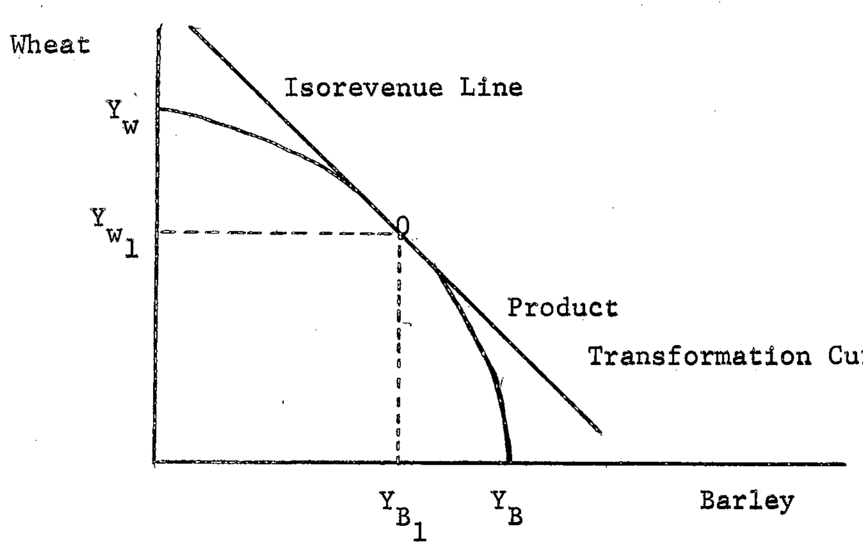

Figure 1. Profit Maximization of Wheat and Barley with Isorevenue Line and Product Transformation Curve.

If all the available resources were used to produce wheat, Y_W amount would be produced. If all available resources were used to produce barley, Y_B would be produced. The optimum combination is at Y_{W_1} for wheat and Y_{B_1} for barley.

Choice in the use of resources for alternative products affects the net returns to the fixed resources. The overall purpose is to achieve a maximum return from given resources. When products are competitive, the optimum allocation of fixed resources between enterprises can be made only if the choice criterion is known. For farm profit maximization, product price ratios provide the choice indicator. Maximum profits are attained, with costs for resources fixed in quantity, when the marginal rate of product substitution is inversely equal to the product price ratio. For products Y_1 and Y_2, the condition of maximum profits is given in equation (3):

(3) $$\frac{dY_1}{dY_2} = \frac{P_{y_2}}{P_{y_1}}$$

Where dY_1/dY_2 refers to the marginal rate of substitution of Y_2 for Y_1, P_{y_1} and P_{y_2} refer to the prices of Y_1 and Y_2, respectively. When the substitution and price ratios have been equated the resources are allocated to maximize profits and the marginal value product of a unit of resource allocated to Y_1 is equal to the marginal value product of a unit of resource allocated to Y_2.

The marginal analysis concepts are used by the linear programming model developed in the next section.

Linear Programming Models

The marginal analysis procedure outlined in the preceding section assumed that the existing transformation relationships were continuous and nonlinear. However, the discrete nature of the data available for this study was linear and discontinuous. Linear programming is an operational technique to analyze problems involving linear relationships.

Linear programming may be used to allocate scarce farm resources to the most profitable and/or least cost use. There are many types of problems to which linear programming can be adapted. The application of linear programming to a specific problem requires that the problem possess three quantitative components: (1) an objective, (2) various alternatives for attaining the objective, and (3) one or more resource restrictions.[1]

Four special postulates of linear programming are required to make the model operational.[2] Linearity is the first assumption. It refers to the constant production relationships and constant prices received and paid. The constant ratios between two resources and between each resource and the product are illustrated in Figure 2. Each straight line from the origin indicates an activity representing the constant ratio between corn silage and barley.

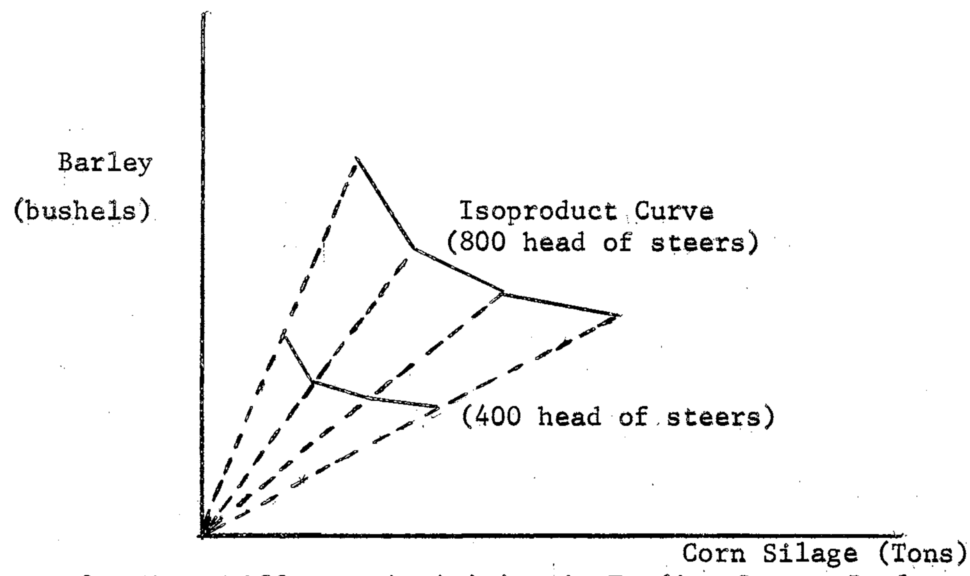

Figure 2. Four Different Activities in Feeding Steers Barley and Corn Silage--An Illustration of the Linearity Assumption of Linear Programming

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[1]Earl O. Heady, Economics of Agricultural Production and Resource Use, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1952, p. 47.

[2]Earl L. Swanson., "Programming and Optimal Farm Plans," Farm Size and Output Research, Southern Cooperatives Bulletin No. 56, p. 47.

Divisibility of activity levels and resource requirements is the second assumption. Fractional activity levels in solutions are rounded to complete units. Then the fractional activities can be rounded, if desirable. The third assumption is that activities in the optimal solution be additive. The general nature of this assumption is that two or more activities can be used simultaneously, subject to the fixed factors available to the farming operation. Then, the quantities of the outputs and inputs will be arithmetic sums of the quantities which would result if the activities were used separately. The fourth and last assumption, finiteness, means relatively few activities are selected as possible alternatives for this problem or any real world problem.

In this study, linear programming was used to determine the highest net return from the farm organization and the least cost blending materials for fertilizer. The principal difference between the maxiimizing and minimizing model is the form of the objective function.

The objective function of the profit maximizing model is of the general form

(4) $$Z = \sum_{j=1}^{n} C_j X_j,$$

where Z represents profit, the C_j's are costs per unit of input or net returns per unit of output, the X_j's are the activities or enterprises, and n is the number of activities considered. The objective function is maximized subject to a set of restrictions expressed as follows:

(5) $$\sum_{j=1}^{m} A_{ij} X_j \leq b_i$$

(6) $$X_j \geq 0$$

In equation 5, A_{ij} is the quantity of the i^{th} resource required in the production of one unit of the j^{th} product (X_j). The b_i's are the resource restrictions with m being the number of restrictions. Equation 6 stipulates that no product can be produced at a negative level.

A diagramatic example of the production possibilities in a profit maximizing model is illustrated in Figures 3 and 4. The isoresource lines in Figure 3 representing land, labor, and capital indicate the possible combinations of wheat and barley which can be produced. The capital line indicates the possible combinations of wheat and barley which can be produced with a given quantity of capital. The amount of capital and land prevents labor from being completely utilized. The amount of land prevents capital from being completely utilized above b, and the limited amount of capital prevents land from being completely utilized below b. Thus, the relevant production possibility curve becomes abc as shown in Figures 3 and 4. Also, the enterprise combinations yielding the highest net return to fixed resources is at b in Figure 4. The combination is quite stable because the price ratio can vary over a wide range before crop combination b becomes less profitable than either a or c.

The objective function for the cost minimization model is as follows:

$$V = \sum_{j=1}^{n} C'_j X_j \qquad (7)$$

where V represents variable costs, the quantity C'_j is the cost required per unit of the j^{th} product and X_j is the quantity of the j^{th} product produced. The objective is to minimize the variable cost (V in equation 7) associated with producing some specified output. The remaining restrictions are similar to the maximization model.

A hypothetical example of the cost minimizing combination of resources for producing a specified level of output is illustrated in Figure 5. The isoproduct curve is made up of linear segments (abc) because of the constant ratios between two basic grades of fertilizer and the product level. The objective is to select a point such as b, which represents the least cost method of producing the desired analysis.

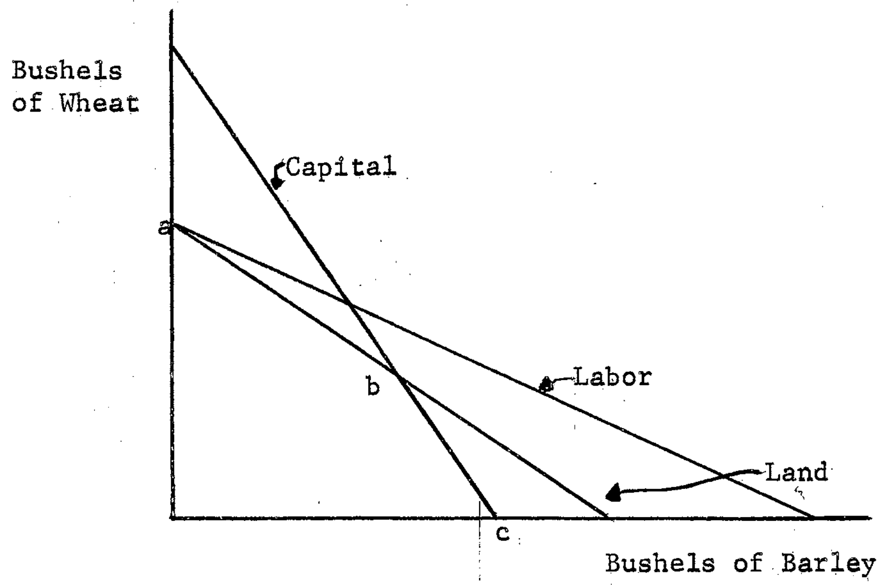

Figure 3. Production Possibilities as Defined by the Limiting Resources in a Linear Programming Model

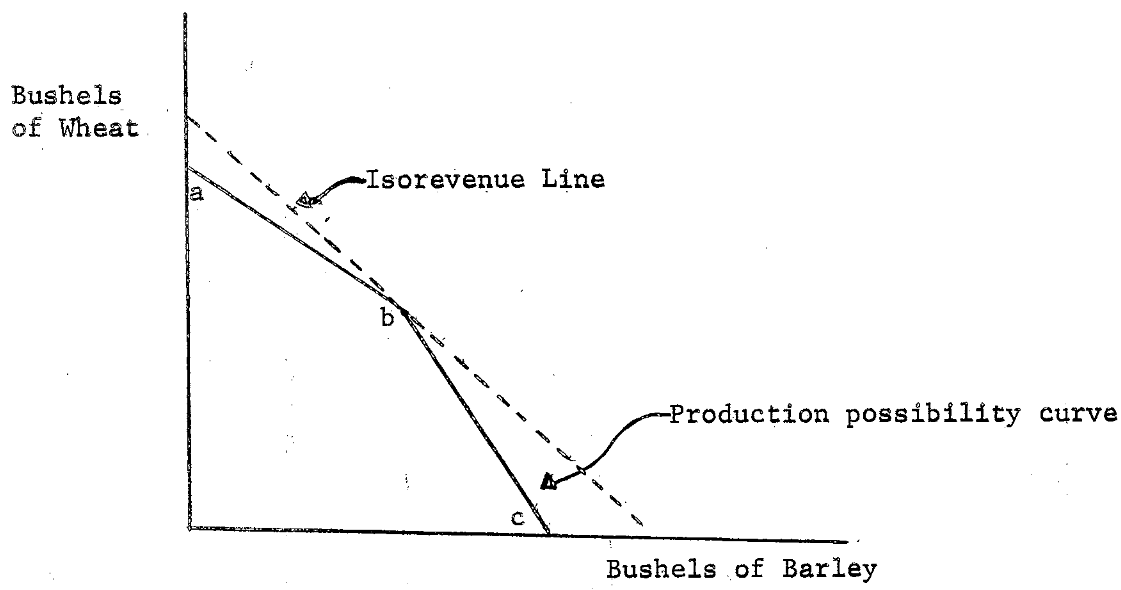

Figure 4. Relevant Production Possibility Curve in a Profit Maximizing Linear Programming Model

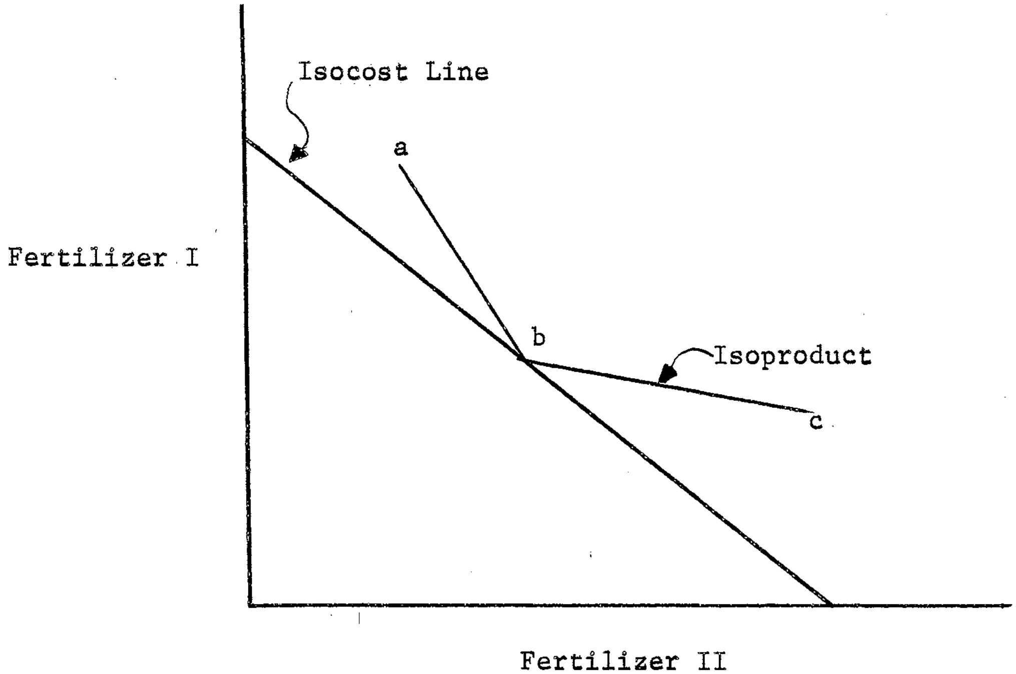

Figure 5. Isoquant and Isocost Lines Used in Obtaining the Optimum Solution with Minimum Cost Model

The cost minimizing combination of resources at point b is relatively stable. The price ratio has a wide range in which to vary before another combination of resources, such as point c, represents the least cost method of production.

A linear programming model can evaluate a large number of production possibilities. In comparison to marginal analysis, linear programming is much more suitable for solving decision problems that do not possess such properties as continuity and concavity.[3]

Programmed budgeting is another technique which could be used as an approach to determining an optimum solution.

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[3]Thomas H. Naylor, "The Theory of the Firm: A Comparison of Marginal Analysis and Linear Programming," The Southern Economic Journal, Vol. XXXII, No. 3, Jan. 1966, p. 267.

Programmed Budgeting

The programmed budgeting technique used in farm planning is a useful tool in determining the exact combination of alternatives that will provide the greatest return to fixed resources. Budgeting is a trial and error process through which the planner hopes to discover an optimum allocation of resources.[4] In fact, linear programming is a mathematical method of budgeting. Both procedures depend upon linear relationships and are basically the same. The only differences are the number of alternatives that can be considered and the calculations involved. In some cases programmed budgeting techniques may be more economical than linear programming. These cases would be when few cropping enterprises are available.

The programmed budgeting procedure utilizes four tables and an eight step computational procedure to arrive at the optimum combination of enterprises. The first table summarizes the resources available and the resource requirements for the enterprises considered. The second table shows the net returns per unit of resource used by each enterprise. In other words, the second table indicates the relative efficiency with which each enterprise uses each limited resource. The third and fourth tables are work tables. They are used in combination with the eight-step computational procedure to determine the optimum combination of enterprises and/or the imput combination that yields the highest net return.

The problem of selecting an optimum input combination relates to the farm manager's inability to equate marginal value product with the

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[4]Donald C. Huffman, Programmed Budgeting--A Tool for Complete Farm Planning, AEA Information Series No. 2, 1965, p. 2.

marginal resource cost referred to in Chapter I. Programmed budgeting can be used as a tool to determine the optimum input combination that will yield the highest net return. In order to have varied input combinations the farmer must have sufficient knowledge of the input-output results conducted on his farm or at least under similar conditions within his locality. In this experiment, it was found that raw data for the factor-product type model was not available, especially in the area of varied fertilizer rates with associated yields.

Marginal analysis, linear programming and programmed budgeting have particular uses in determining the optimum organization. The programmed budgeting procedure is suited best for field work and when few alternatives are being analyzed. A more detailed explanation is given in Huffman's article.

The appendix section describes possible theoretical fertilizer recommendation procedures that can be used by the dealer and farmer. The outlined procedures certainly are an addition to satisfying the third objective of this study. This objective is to increase the knowledge of each fertilizer dealer pertaining to the farm enterprises. The recommendation procedures can supplement the linear programming solutions.

Chapter III

LINEAR PROGRAMMING AS A DEALER SERVICE TO FARMERS--AN EXPERIMENT

Major steps in the experiment were (1) arranging for involvement of dealers and farmers, (2) collection of input-output data for individual farms (3) development of the linear programming model and (4) evaluation of the results. Each is described, in turn, in this chapter.

Dealer-Farmer Involvement--The Experiment

The experiment was initiated by selecting three fertilizer dealers in North Central Oklahoma who had participated in a fertilizer dealers workshop. The dealers were chosen because of their keen interest in the computerized service. The dealers, in turn, selected farmer customers to participate in the computerized programming experiment. Two of the dealers worked with two farmers and one worked with three farmers.

In anticipation of the dealer and farmer experiment, the fertilizer dealers conference presented an opportunity for the dealers to learn the uses of the computer in solving dealer and farmer problems. The conference was designed to expose possible solutions to the economics and physical decision making problems of dealers and their farm customers. Table I is a list of the sessions presented at the workshop. The conference was staffed by Oklahoma State University agricultural economists and agronomists. Comments from the dealers helped in designing the experiment with specific dealers and farmers in this study.

TABLE I

OKLAHOMA FERTILIZER DEALERS AND BLENDERS CONFERENCE
March 13-14, 1968

Section	Session
	The Economic-Physical Climate for Decision Making--William L. Brant
A.	Data for Decision Making
	1. Crop Response to Fertilizer--B. B. Tucker
	2. Estimating Area Fertilizer Demand--Leroy C. Quance
	3. Using Response Data in a Decision Making Model--Vernon R. Eidman
	Profitable Fertilizer Use
B.	Budgeting Alternatives
	1. Enterprise Budgets--Odell L. Walker
	2. Methods of Application--Vernon R. Eidman
	3. Timing of Application--William L. Brant
C.	The Whole Farm Profit Picture
	1. Developing the Simplified Programming Matrix--Odell L. Walker
	2. Programmed Analysis--Gary M. Mennem
	3. Computerized Computations--Gary M. Mennem
D.	Least Cost Blending--Ted R. Nelson
E.	Profitable Fertilizer Sales
	1. Fertilizer Pricing Alternatives--Larry Roberts
	2. Machinery Rental and Custom Service Analysis--William L. Brant
F.	Planning Under Imperfect Knowledge
	1. Optimum Fertilizer Use Under Different Economic and Production Conditions--Gary M. Mennem
	2. Planning Strategies for Variable Weather Conditions--Ted R. Nelson

The Crop Response to Fertilizer session of the workshop outlined results of some of the latest field trials conducted to the various research stations over the state. In a following session, the response data were used to develop a decision model the dealers could use to take results from field trials and help farmers determine profitable fertilizer rates. Other sessions had discussions on methods and timing of applications and planning strategies for variable weather conditions.

An example was presented to the dealers on farm planning of the various crops and different fertilizer rates associated with these crops. A representative farm from North Central Oklahoma was used for the example. Many specific questions arose pertaining to this farm. Some of the questions could not be fully answered because the farm was not specifically suited to interests of all participants. Therefore, it was determined that a farm must contain the specific conditions, alternatives and resources confronted by the farmer in order to answer the specific questions pertaining to a particular farm organization.

Some of the workshop sessions were designed to assist dealers in solving problems internal to their business. One topic presented a method for the dealer to use in estimating his area demand for fertilizer. The information to estimate the demand could be complied from fertilizer consumption reports published for the state and county. Another topic for dealers was a machinery rental and custom service analysis. An approach to determining break-even usage of the various machines such as fertilizer spreaders and other equipment also was presented.

The remaining topics were designed to explain problems which the computer could solve for the dealer and his farm customer. The computerized least cost blending topic was of major interest to the dealers. Each had an opportunity to submit a problem that was returned the second day of the conference. The least cost blending application will be discussed further in Chapter IV.

It was decided that from the questions and comments made by the dealers at the workshop that a representative farm could not answer specific organizational and environment questions of a farmer or dealer. The farm programming experiment was then conducted with seven specific farms. These farmers were chosen by three of the dealers that had attended the blenders conference and expressed a great interest in the farm programming service. The dealers thought that they could determine better fertilizer recommendation rates with the computer service for each farmer. The farmer and dealer could then determine the best fertilizer program. The dealers, by offering the computerized programming service, could increase his fertilizer sales volume by gaining customers or selling more fertilizer to his present customers. But in order to sell more fertilizer to his present customers, the farmer would have to be more confident of increasing his per acre returns.

After selection of the dealers and farmers, it was necessary to develop a good understanding of the purpose of linear programming and the information the dealer and farmer would contribute. It was not deemed necessary that the farmer and the dealer understand the actual mechanics of developing a linear programming matrix, but just be able to assemble the needed information. That is, availability of the service was assumed, for example, through a private business or a university. It is important that each understand the information required to develop the linear programming service.

There is no limit to the size of farm number of activities or types of activities that can be considered for the programming service. Important differences existed among the seven farm organizations in the experiment. Table II gives the resources which each farm possessed. These resource inventories were developed in consultation with each cooperating farmer and his fertilizer dealer. Diversion requirements for each crop were omitted from Table II because the farmer has the alternative to participate or not participate in each government program. The diversion alternatives were allowed in the computer program.

Obtaining Data for Linear Programming

The overall guide for gathering data is provided by key parts of a linear programming problem. Data are needed to develop the objective function, specify the alternatives and define the restrictions which limit the alternatives. These three components of a linear program were discussed in Chapter II. The primary reason the experiment was limited to seven farm organizations was to allow time for emphasis on detailed analysis of results and specific alternatives to individual problems associated with providing a linear programming service.

The collection of pertinent input-output data to build the linear programming matrix is the initial step to achieving good results. In a linear programming service such as is proposed, data gathering must be done as efficiently and simply as possible. But in striving for efficiency and simplicity, the input data must represent the conditions of the programmed farms as closely as possible. One point which cannot be over emphasized is that the optimum solutions are no better than the input data used in the linear program.

An opportune time to collect resource information might be when soil samples are being taken from the fields; although a less busy time could be chosen. Most dealers furnish the soil testing service at the present time. As a basis for fertilizer recommendations, the simultaneous acts

TABLE II

RESOURCES OF THE SEVEN FARM ORGANIZATIONS
INVOLVED IN THE PROGRAMMING EXPERIMENT

Resources	Unit	Farm I	Farm II	Farm III	Farm IV	Farm V	Farm VI	Farm VII
Cropland	Acres	920.0	791.9	538.0	330.0	153.8	562.2	777.1
Wheat Allotment	Acres	244.3	402.9	335.6	184.2	69.4	276.8	302.4
Barley Allotment	Acres	120.0	92.0	71.0	38.0	74.0	148.0	198.0
Feed Grain Allotment	Acres	106.0	36.0	0.0	0.0	0.0	0.0	0.0
Oats Allotment	Acres	0.0	0.0	0.0	0.0	0.0	0.0	20.0
Rye Allotment	Acres	0.0	60.2	0.0	0.0	0.0	0.0	0.0
Labor	Hours	10000.0	Unlimited	2000.0	2500.0	300.0	2000.0	3000.0
Operating Capital	Dollars	Unlimited	Unlimited	5000.00	7500.00	5000.0	6000.00	Unlimited
Native Pasture	AU	0.0	470.5	0.0	400.0	0.0	316.0	391.0
Feedlot Capacity	AU	800.0	0.0	0.0	0.0	0.0	0.0	0.0

of gathering soil samples and computer program invformation will likely minimize the time required per farm customers to obtain all the information needed.

The farmer must determine what enterprises will be considered for the computer program[1] and a budget for each type of enterprise must be constructed. Existing budgets for North Central Oklahoma were used as a pattern for the farmer's personal budgets.[2] Using these budgets as a pattern consumes much less time than trying to develop the whole budget in which some repetition is certain to occur. Only variable costs were used in development of the budgets because the goal is to assist the farmer to make decisions for next year or shorter run. In solving for the optimum solutions for the next crop year, costs for fixed inputs can be assumed constant between alternative plans. Costs treated as fixed include those associated with land, machinery ownership and buildings.

Cropping Enterprises

Cooperating farmers selected wheat, barley, grain sorghum, corn silage, rye, oats, sudan, and alfalfa as possible alternatives. After each farmer had selected the crops to be considered in the computer program, existing budgets were reviewed with each farmer to determine production practices and variable production cost per acre of each crop. The fertilizer cost was not included because the model was constructed to allow alternative fertilizer rates for crop alternatives and compute

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[1]The term "computerized program" will refer to the linear program solved by the computer.

[2]Larry J. Conner, Hollis D. Hall, Odell Walker, and Jim Tomlinson, Alternative Crop Enterprises on Clay and Loam Soils of North Central Oklahoma, Processed Series P-550, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, Oklahoma, October 1966.

total fertilizer use. A separate crop activity was constructed for fertilizer yield combinations for which farmers and dealers provided information.

The yields which were predicted by the farmer were determined either by the farmers past fertilizer record or by using information in which the farmer held a high degree of confidence. This information was usually from neighboring farmers, county extension agents, fertilizer dealers or county fertility trails. Often experimental fertilizer rates and yields could not be used by the cooperating farmer to classify the soils on his farm and interpolate fertilizer input--crop yield information. The soil grouping was done in such a manner as to represent the farmer's classifications rather than the county soil conservation classifications. As an example, Table III gives the soil classifications chosen for farm IV. The county soil conservation classifications were used on one farm.

TABLE III

FARMER CHOSEN SOIL CLASSIFICATIONS FOR FARM IV

Total Cropland	330 Acres
Upland Type 1	235 Acres
Upland Type 2	75 Acres
Bottomland	20 Acres

Farm IV is used in the following examples to illustrate the number of crop alternatives which can be developed from the three soil types and three fertilizer rate--yield relationships accepted by the farmer. Farm IV was the only farm in this experiment that had three fertilizer rates associated with the known yields for wheat production. Table IV indicates the predicted yields associated with farm IV.

TABLE IV

PREDICTED YIELDS FOR FARM IV

Crop	Soil Type	N-P-K[1]	Unit	Amount
Wheat	Upland #1	(45-46-0)	Bu./A	28
		(50-46-0)	Bu./A	31
		(55-46-0)	Bu./A	33
	Upland #2	(45-46-0)	Bu./A	27
		(50-46-0)	Bu./A	30
		(55-46-0)	Bu./A	32
	Bottomland	(45-46-0)	Bu./A	30
		(50-46-0)	Bu./A	33
		(55-46-0)	Bu./A	35

[1]The fertilizer is given in actual pounds of nutrient applied per acre. Yields were determined from farmer experience with fertilizer use.

With the price of wheat at $1.20 per bushel and nitrogen at $.08 per pound, wheat on Upland #1 soil will have the highest net return when 55 pounds of nitrogen is applied. But if the farmer wants to maximize profit per acre of wheat land, he should apply fertilizer until the cost of one additional pound of fertilizer is equal to the value of the increase in yield. The problem of determining the most profitable fertilizer rate faces every farmer. This is a question that the computer program cannot solve unless the rate and yield information is known. Therefore the farmer must rely on other sources of information such as the fertilizer dealer.

Figure 6 shows three known fertilizer rates with the associated yield. A production function can be projected according to agronomists' best judgments to estimate the most profitable fertilizer rate.

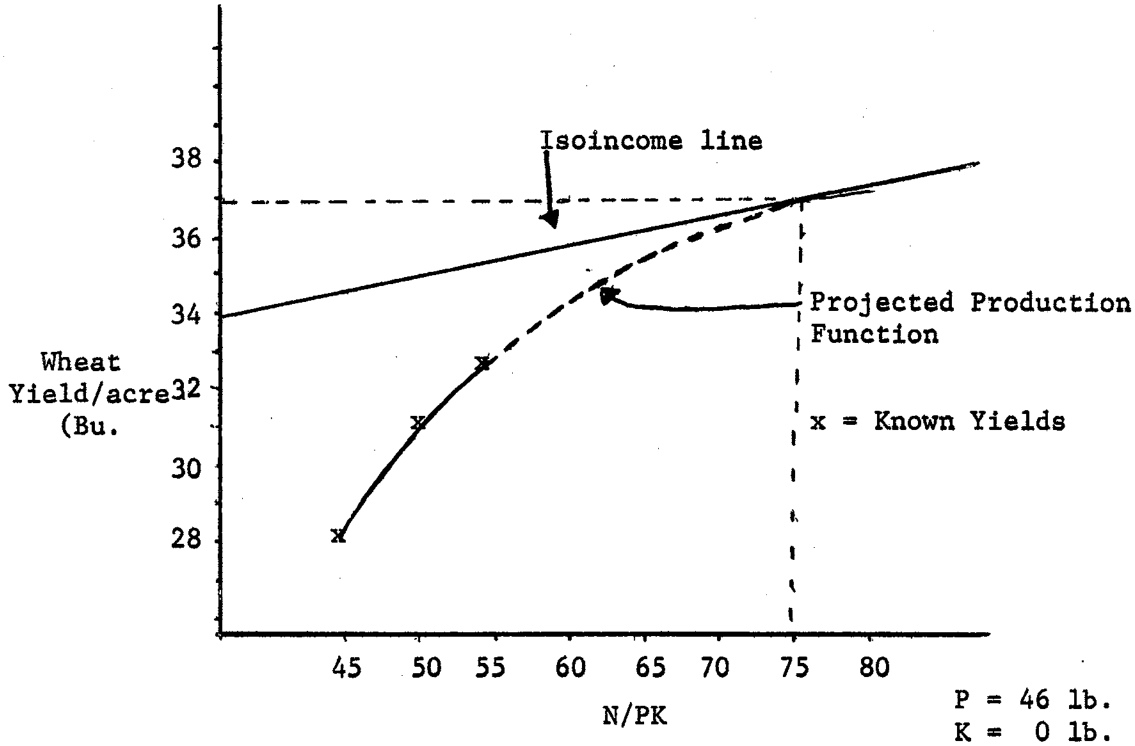

Figure 6 Projected Production Function to Determine Maximum Profit Point.[3]

The most profitable amount of nitrogen to apply is shown graphically by Figure 1 and theoretically determined by the following:

(1) $$\frac{P_n}{P_w} = MPP_n$$

(2) $$P_n = MPP_n \cdot P_w$$

P_n is the price of nitrogen and P_w is the price of wheat. MPP_n is the marginal physical product of nitrogen used in the production of wheat.

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[3]Wheat was valued at $1.20 per bushel and nitrogen was valued at $.08 per pound to determine the most profitable point. The domestic marketing certificates were not added to the price of wheat because of the uncertainty of future certificates. But if certificates were for the future, there would be a great advantage to increasing yields greater than maximizing profit in a given year. Once a yield greater than the county average has been proven for three consecutive years, the certificate value per acre will increase. Presently, farm IV is using the county wheat average of 28 bushels per acre. If the farm could prove a yield of 36 bushels per acre, as determined by the projected function, an additional $4.74 per acre of wheat allotment could be gained.

This approach is the same as indicated in the marginal analysis section in Chapter II.

Government Program Alternatives

One of the most important problems facing the farmer is determining what degree of government program participation would maximize net returns. If a farmer participates in the wheat program for example, the allotment and diverted acre restrictions must be observed to receive domestic marketing certificates.

In order to determine the alternative that will maximize net returns, six alternative right hand sides were developed in the computer programming service. Each right hand side (RHS) pertains to a different government program alternative. Table V explains the six alternative right hand sides for farm II. Farm II is used as an example because it has allotments for wheat, feed grain and barley. These three allotments are needed in order to explain all six alternatives. Farm IV did not have a feed grain base, therefore all of the government program alternatives could not be analyzed to provide a complete example of this aspect of the analysis.

RHS1 is the alternative to not participate in any government program. Total cropland is the first to restrict the planting of the most profitable crop. The allotments are set at a high value, 9999 acres, so that they do not restrict choice.

RHS2 allows the farmer to participate in the wheat program only. The wheat allotment for farm II is 402.9 acres. But the farmer must also divert 15% of the 1969 farm wheat allotment to conserving uses. This sets a restriction on the minimum diversion amount. The diverted acreage must be greater than or equal to 60.4 acres. A farmer can also plant

TABLE V

RIGHT HAND SIDE ALTERNATIVES FOR FARM II

	RHS1	RHS2	RHS3	RHS4	RHS5	RHS6
Cropland (COPLD)	791.9	791.9	791.9	791.9	791.9	791.9
#1 Upland (UPLD1)	201.7	201.7	201.7	201.7	201.7	201.7
#2 Upland (UPLD2)	290.0	290.0	290.0	290.0	290.0	290.0
#3 Upland (UPLD3)	89.0	89.0	89.0	89.0	89.0	89.0
#1 Bottomland (BOTM1)	86.6	86.6	86.6	86.6	86.6	86.6
#2 Bottomland (BOTM2)	40.0	40.0	40.0	40.0	40.0	40.0
#3 Bottomland (BOTM3)	84.6	84.6	84.6	84.6	84.6	84.6
Barley Allotment (BALLT)	9999	9999	92.0	92.0	92.6	92.6
Wheat Allotment (WTALT)	9999	402.9	402.9	402.9	402.9	402.9
Sorghum Allotment (SOALT)	9999	9999	36.0	36.0	36.0	36.0
Rye Allotment (ORALT)	9999	9999	60.2	60.2	60.2	60.2
Barley Minimum Diversion (MDB)	--	--	--	--	13.8	--
Sorghum Minimum Diversion (MDS)	--	--	7.2	7.2	7.2	7.2
Rye Minimum Diversion (MDR)	--	--	--	--	9.0	--
Maximum Sorghum Diversion (DAS)	--	--	18.0	18.0	18.0	--
Wheat Minimum Diversion (MDW)	--	60.4	60.4	60.4	60.4	60.4
Wheat Maximum Diversion (DAW)	--	201.4	201.4	--	--	201.4
Fallow (FAL)	--	--	--	--	--	--
Sorghum for Wheat (SFWL)	--	--	--	--	--	201.4
Wheat for Sorghum (WFSL)	--	--	--	26.8	26.8	--
Wheat for Barley (WFBL)	--	--	--	--	78.2	--
Wheat for Rye (WFRL)	--	--	--	--	--	--
Sorghum Certificate Limit (SPL)	--	--	36.0	36.0	36.0	36.0
Wheat Certificate Limit (WCL)	--	402.9	402.9	402.9	402.9	402.9
Wheat Production (WTPRD)	--	--	--	--	--	--
Barley Production (BAPRD)	--	--	--	--	--	--
Sorghum Production (SOPRD)	--	--	--	--	--	--
Rye Production (RYPRD)	--	--	--	--	--	--
Alfalfa Production (ALPRD)	--	--	--	--	--	--
Nitrogen (NITRO)	--	--	--	--	--	--
Phosphorus (PHOSP)	--	--	--	--	--	--
Potassium (POTAS)	--	--	--	--	--	--
Operating Capital (CAPIT)	--	--	--	--	--	--
Annual Labor (LABOR)	--	--	--	--	--	--
January - April Labor (LABJA)	--	--	--	--	--	--
May - July Labor (LABMJ)	--	--	--	--	--	--
August - September Labor (LABAS)	--	--	--	--	--	--
October - December Labor (LABOD)	--	--	--	--	--	--
Native Pasture (PASTR)	470.5	470.5	470.5	470.5	470.5	470.5
Wheat Pasture (WHTPT)	--	--	--	--	--	--

less than the full allotment, earn diversion payments and qualify for the domestic marketing certificates. The latter alternatives can be accomplished by diverting a maximum of 50% of the allotment, represented by 201.4 acres in the maximum diversion restriction, and meeting other program requirements. The maximum of certificates is represented by 402.9 as the wheat certificate limit.

RHS3 allows participation in the wheat and feed grain programs with no substitution of allotments between programs. The wheat program restrictions are the same as RHS2. The barley allotment, 92 acres, the feed grain allotment, 36 acres, and the rye allotment, 60.2 acres, are added to the computer program. The feed grain program requires a 20% diversion of the allotment to qualify for the domestic marketing certificates. The minimum diversion amount is 7.2 acres. A diversion payment may also be earned by diverting 50% of the allotment, a maximum of 18 acres. Also, the maximum feed grain certificates that can be earned is 36, the same as the allotment.

RHS4 allows participation in the wheat and feed grain programs with the additional option to substitute 80% of the feed grain allotment to gain additional wheat acreage. This right hand side is very similar to RHS3 except no diversion payment may be earned and the 80% substitution of wheat for sorghum limit, 26.8 acres must be observed.

RHS5 reflects the possibility of gaining additional wheat acreage from giving up 85% of the barley allotment and 80% of the feed grain allotment through the substitution provisions of the wheat and feed grain programs. In addition, the 15% and 20% acreage allotment from barley and feed grain, respectively, must be devoted to conserving uses. Rye allotment can be planted to wheat if 15% is diverted to conserving uses.

RHS6 allows the participation in the wheat and feed grain programs with the option to substitute additional feed grain acreage for the wheat allotment. This alternative is only used when grain sorghum production is more profitable than wheat production.

Livestock Enterprises

Often the farm operation includes more than just cropping enterprises. Livestock enterprises can be included in the computer program. It was found in this experiment that grain and wheat pasture were used for livestock without analyzing whether it was more profitable to sell the crop or feed it and sell the animal.

The simplest method of inserting livestock enterprises into the linear program is to determine the net return excluding all farm grown or produced inputs.

Pasture production is measured in terms of animal unit months of grazing (AUM). One AUM is the amount of grazing required by one animal unit for one month. An animal unit is defined as 1 mature cow and calf. Growing cattle are converted to animal units on the basis of weight as follows:

$$AU = \frac{\text{Average weight of animal}}{\text{1000 lbs.}}$$

The AUM's of grazing produced per acre is an estimate of the number of animal units that can be grazed for one month, or alternatively, the number of months one animal unit could be grazed on one acre. For example, assume that ten acres of range will carry one cow and calf for twelve months. The AUM's per acre can be determined by:

$$\frac{12\text{(months)} \times 1\text{(AU)}}{10\text{ (acres)}} = 1.2\text{ AUM per acre}$$

One AUM of grazing is considered to be roughly equivalent to 450 pounds of total digestible nutrients or 15 pounds of total digestible nutrients per day.

Table V contains one restriction for the livestock enterprises that does not pertain to the cropping enterprises. This restriction is the animal unit months of grazing available from the native pasture. Table XIII is the completed linear programming matrix for farm II. The net returns of each livestock alternative are in the cost row. The cost does not include the farm produced inputs. The cost was excluded in order to determine whether the grain should be sold or fed to the animal and in turn sell the animal.

Capital and labor restrictions usually are used in the linear program. The farmer of farm II stated that labor was available and he could hire all the labor he needed. The farmer also states that he could borrow all the capital he needed for his farming operation.

Reporting Optimum Solutions

Once the computer program has been developed and solved, solutions must be reported to the farmer in a meaningful and concise manner. The report used in this study is divided into three parts; part II and part III are repeated for every government program alternative given in Table III.

Part I of the report consists of (1) resources available, (2) projected yields and (3) the institutional allotments involved in participating in the various government programs. Table VI is an example of the output of part I for farm II.

Part II is a summary of the optimum farm plan presented in Tables VII through XII. It includes the amount of each enterprise needed to maximize net returns to the fixed resources. The required capital and labor are also included.

Part III is the financial summary and is presented in Tables VII through XII. This part gives a detailed listing of the sales and expenses of the farm operation. The price ranges of the crops sold are a

TABLE VI

RESOURCES, YIELDS AND ALLOTMENTS FOR FARM II

Part I	Resource Available	Unit	Amount
	Total Land	Acre	791.9
	#1 Upland	Acre	201.7
	#2 Upland	Acre	290.0
	#3 Upland	Acre	89.0
	#1 Bottomland	Acre	86.6
	#2 Bottomland	Acre	40.0
	#3 Bottomland	Acre	84.6
	Native Pasture	AUM	470.5
	Projected Yields		
	Wheat #1 Upland (38-22-8)	Bu./A	26
	Wheat #2 Upland (38-22-8)	Bu./A	24
	Wheat #3 Upland (38-22-8)	Bu./A	21
	Wheat #1 Bottomland (38-22-8)	Bu./A	24
	Wheat #2 Bottomland (38-22-8)	Bu./A	22
	Wheat #3 Bottomland (38-22-8)	Bu./A	20
	Barley #2 Upland	Bu./A	24
	Barley #3 Upland	Bu./A	22
	Rye #3 Bottomland	Bu./A	30
	Sorghum #3 Upland	Bu./A	34
	Sorghum #3 Bottomland	Bu./A	36
	Alfalfa #3 Bottomland	Ton/A	6
	Institutional Restrictions		
	Wheat Allotment	Acre	402.9
	Barley Allotment	Acre	92.0
	Feed Grain Allotment	Acre	36.0
	Oats and Rye Allotment	Acre	60.2

TABLE VII

OPTIMUM FARM PLAN AND FINANCIAL SUMMARY
FOR GOVERNMENT PROGRAM ALTERNATIVE I ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 1. Non-participation in Government Programs

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	201.7
Wheat #2 Upland (38-22-8)	Acre	290.0
Alfalfa #3 Bottomland	Acre	84.6
Livestock		
Cow-Calf	AU	46.0
Stocker-Feeder Steers	AU	144.0
Required Labor	Hour	1987.0
Required Capital Adjusted to Annual Basis	Dollar	16,378.04
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	26,003.13

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$17,349.79	Bu.	$ .67	$ 1.20	$ 1.87
Alfalfa	14,217.90	Ton	14.42	30.00	Infinite
Government Payments					
Diversion	0				
Certificates	0				
Total	31,567.69				
Operating Expenses	2,398.86				
Fertilizer Expenses					
Nitrogen	1,879.63				
Phosphate	1,088.21				
Potash	197.86				
Total Expense	5,564.56				
Net Return to Land Labor, Management and other fixed Resources	$26,003.13				

TABLE VIII
OPTIMUM FARM PLAN AND FINANCIAL SUMMARy
FOR GOVERNMENT PROGRAM ALTERNATIVE II ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 2 Participation in Wheat Program Only

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	201.7
Barley #2 Upland	Acre	215.4
Sorghum #3 Upland	Acre	89.0
Alfalfa #3 Bottomland	Acre	84.6
Other Land Usage		
Minimum Wheat Diversion	Acre	60.4
Livestock		
Cow-Calf	AU	48.0
Stocker-Feeders Steers	AU	54.0
Required Labor	Hour	1,983.0
Required Capital Adjusted to Annual Basis	Dollar	10,661.88
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	31,505.89

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$ 9,662.88	Bu.	$ .90	$ 1.20	$1.70
Barley	3,877.20	Bu.	.42	.75	1.23
Sorghum	3,389.12	Bu.	.45	1.12	3.86
Alfalfa	14,696.90	Ton	14.42	30.00	Infinite

Government Payments	
Diversion	0.00
Wheat Certificates	6,696.20
Total	38,322.30
Operating Expenses	5,062.81
Fertilizer Expense	
Nitrogen	1,041.20
Phosphate	602.80
Potash	109.60
Total Expense	6,816.41
Net Return to Land Labor, Management and other Fixed Resources	$31,505.89

TABLE IX

OPTIMUM FARM PLAN AND FINANCIAL SUMMARY
FOR GOVERNMENT PROGRAM ALTERNATIVE III ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 3 Participation in Wheat and Feed Grain Programs with no Substitution of Acres Between Programs

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	201.7
Wheat #2 Upland (38-22-8)	Acre	14.2
Barley #2 Upland	Acre	92.0
Sorghum #3 Upland	Acre	28.8
Alfalfa #3 Bottomland	Acre	84.6
Other Land Usage		
Minimum Wheat Diversion	Acre	60.4
Minimum Sorghum Diversion	Acre	7.2
Livestock		
Cow-Calf	AU	48.0
Stocker-Feeder Steers	AU	54.0
Required Labor	Hour	1653.0
Required Capital Adjusted to Annual Basis	Dollar	9,963.9
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	28,749.42

Part III Financial Summary

Crop Sales		Unit	Price Range: Lower Limit	Price Range: Price Used	Price Range: Upper Limit
Wheat	$10,037.76	Bu.	$ .90	$ 1.20	$ 1.70
Barley	1,656.00	Bu.	.39	.75	1.23
Sorghum	1,096.70	Bu.	.80	1.12	66.00
Alfalfa	14,696.90	Ton	14.42	30.00	Infinite
Government Payments					
Diversion	0.00				
Wheat Certificates	6,696.20				
Sorghum Certificates	153.79				
Total	34,137.36				
Operating Expense	3,634.34				
Fertilizer Expense					
Nitrogen	1,041.20				
Phosphate	602.80				
Potash	109.60				
Total Expense	5,387.94				
Net Return to Land Labor, Management and other Fixed Resources	$28,749.42				

TABLE X
OPTIMUM FARM PLAN AND FINANCIAL SUMMARY
FOR GOVERNMENT PROGRAM ALTERNATIVE IV ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 4 Participation in Wheat and Feed Grain Program and Substituting Wheat Acreage for Sorghum Acreage

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	201.7
Wheat #2 Upland (38-22-8)	Acre	14.2
Barley #2 Upland	Acre	92.0
Sorghum #3 Upland	Acre	28.8
Alfalfa #3 Bottomland	Acre	84.6
Other Land Usage		
Minimum Wheat Diversion	Acre	48.0
Minimum Sorghum Diversion	Acre	54.0
Livestock		
Cow-Calf	AU	48.0
Stocker-Feeder Steers	AU	54.0
Required Labor	Hour	1652.9
Required Capital	Dollar	9,963.9
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	28,749.42

Part III Financial Summary

Crop Sales		Unit	Price Range: Lower Limit	Price Used	Upper Limit
Wheat	$10,037.76	Bu.	$ .90	$ 1.20	$ 1.70
Barley	1,656.00	Bu.	.40	.75	1.23
Sorghum	1,096.71	Bu.	.80	1.12	66.00
Alfalfa	14,496.90	Ton	14.42	30.00	Infinite
Government Payments					
Wheat Certificates	6,696.20				
Sorghum Certificates	153.79				
Total	34,137.36				
Operating Expense	3,634.34				
Fertilizer Expense					
Nitrogen	1,041.20				
Phosphate	602.80				
Potash	109.60				
Total Expense	5,387.94				
Net Return to Land Labor, Management, and other Fixed Resources	28,749.42				

TABLE XI
OPTIMUM FARM PLAN AND FINANCIAL SUMMARY
FOR GOVERNMENT PROGRAM ALTERNATIVE V ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 5 Participation in Wheat and Feed Grain Program with Substitution of Wheat for Sorghum and Wheat for Barley

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	201.7
Wheat #2 Upland (38-22-8)	Acre	92.4
Sorghum #3 Upland	Acre	28.8
Alfalfa #3 Bottomland	Acre	84.6
Other Land Usage		
Minimum Barley Diversion	Acre	13.8
Minimum Sorghum Diversion	Acre	7.2
Minimum Wheat Diversion	Acre	60.4
Substituted Acres		
Wheat for Barley	Acre	78.2
Livestock		
Cow-Calf	AU	48.0
Stocker-Feeder Steers	AU	79.0
Required Labor	Hour	1658.0
Required Capital	Dollar	11,553.97
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	29,441.60

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$12,102.24	Bu.	$ .90	$ 1.20	$ 1.70
Sorghum	1,096.70	Bu.	.80	1.12	66.00
Alfalfa	14,496.90	Ton	14.42	30.00	Infinite
Government Payments					
Wheat Certificates	6,696.20				
Sorghum Certificates	96.12				
Total	34,488.16				
Operating Expense	2,892.58				
Fertilizer Expense					
Nitrogen	1,278.93				
Phosphate	740.43				
Potash	134.62				
Total Expense	5,046.56				
Net Return to Land, Labor, Management and other Fixed Resources	$29,441.60				

TABLE XII
OPTIMUM FARM PLAN AND FINANCIAL SUMMARY
FOR GOVERNMENT PROGRAM ALTERNATIVE VI ON FARM II

Part II Summary of the Optimum Farm Plan

Alternative 6 Participation in Wheat and Feed Grain Program with Alternative to Substitute Sorghum Acreage for Wheat Acreage

Crops	Unit	Amount
Wheat #1 Bottomland (38-22-8)	Acre	86.6
Wheat #2 Bottomland (38-22-8)	Acre	40.0
Wheat #1 Upland (38-22-8)	Acre	155.7
Barley #2 Upland	Acre	92.0
Sorghum #3 Upland	Acre	89.0
Alfalfa #3 Bottomland	Acre	84.6
Other Land Usage		
Minimum Sorghum Diversion	Acre	7.2
Minimum Wheat Diversion	Acre	60.4
Wheat Diversion Payment	Acre	14.4
Substituted Acres		
Sorghum for Wheat	Acre	60.2
Livestock		
Cow-Calf	AU	48.0
Stocker-Feeder Steers	AU	34.0
Required Labor	Hour	1,633.6
Required Capital	Dollar	8,680.34
Net Return to Land, Labor, Management and other Fixed Resources	Dollar	29,304.97

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$ 8,338.08	Bu.	$ .83	$ 1.20	$1.56
Barley	1,656.00	Bu.	.40	.75	1.33
Sorghum	3,389.12	Bu.	.87	1.12	4.48
Alfalfa	14,692.80	Ton	14.42	30.00	Infinite
Government Payments					
Diversion	0.00				
Sorghum Certificates	96.12				
Wheat Certificates	6,696.20				
Total	34,868.32				
Operating Expense	4,117.97				
Fertilizer					
Nitrogen	858.19				
Phosphate	496.85				
Potash	90.34				
Total Expense	5,563.35				
Net Return to Land Labor, Management and other Fixed Resources	$29,304.97				

very important part of the financial summary. The limits of the price ranges give an indication of how stable the present optimum enterprise is in relation to the present price of the product sold.

Results of Application with Dealers anf Farmers

One of the dealers participating in the experiment thought the computer service could partially replace his advertising expenditures. All three dealers would like to have the service tried on more of their customers. But the dealers wanted the computer service extended to them only if it would cost them less than the net returns received from additional fertilizer sales.

The cooperating farmers that gained the most information from the program were the ones with the largest crop operations and with a wheat and feed grain allotment. These farmers had more government program alternatives. It was found in this experiment that the farmers did not know per acre or per unit costs and returns, before constructing the enterprise budgets. Many of farmers had good personal records for income tax purposes. With the experience gained from participating in the experiment, all seven farmers planned to keep better or different production records on each enterprise in addition to the total farm records.

The cooperating farmers were very interested in the results of the six government program options such as presented in Tables VI through XI. One farmer cited the fact that he faces a different farm program every year. He was certain that the computer program would help him make a better decision for the coming crop year. The results of this experiment were given to the farmers prior to the fall small grain planting season. The farmers could then use the computer program results as a guide for the next years crop organization and as a fertilizer rate guide. A summary was made for each farmer which explained each alternative plan and told which plan would yield the highest net return. For example, alternative II yielded the highest net return for farm II. This alternative was to participate only in the wheat program. Tables VII through XII summarizes each alternative for farm II.

The linear programming matrix for farm II is presented in Table XIII with the description of the column abbreviations in Table XIV.

Income Approach to Land Purchase

To illustrate other applications of Linear Programming with which dealers can provide a service, the opportunity to purchase an additional tract of land was analyzed. The problem is to determine the price that can be paid.

The income or productivity value can be determined with a minimum amount of calculation. Once the present farm operation has been developed and the optimum combination of enterprises determined, the additional land can easily be added to the computerized program. Two assumptions must be made in that the additional land added to the program does not exceed the linear restrictions and other inputs do not change.

Once again, the input-output information must be gathered and assembled by the farmer. The information must be derived from the present owner or tenant.

The income approach to value is based upon the income potential of the land. The annual income potential is then capitalized at a rate, expected by or acceptable to the farmer or other buyers who have purchased comparable tracts in the area. To discover the acceptable capitalization rate one divides the price paid by other buyers into the net returns these buyers can reasonably expect from the land purchased. It does not

TABLE XIII

LINEAR PROGRAMMING MATRIX FOR FARM II

	MDBA	MDSA	MDRA	MDWA	WDPAY	SDPAY	FAL	SFW	WFS	WFB	WFR	WCA	SCA	N	P	K
Cost	0	0	0	0	-17.50	-4.81	+4.00	0	0	0	0	-16.62	-5.34	.08	.08	.04
Cropland (COPLD)							1.0									
#1 Upland (UPLD1)																
#2 Upland (UPLD2)																
#3 Upland (UPLD3)																
#1 Bottomland (BOTM1)																
#2 Bottomland (BOTM2)																
#3 Bottomland (BOTM3)																
Barley Allotment (BALLT)	1.0									1.0						
Wheat Allotment (WTALT)				1.0	1.0			1.0	-1.0	-1.0	-1.0					
Sorghum Allotment (SOALT)		1.0				1.0		-1.0	1.0							
Rye Allotment (ORALT)			1.0								1.0					
Barley Minimum Diversion (MDB)	1.0															
Sorghum Minimum Diversion (MDS)		1.0														
Rye Minimum Diversion (MDR)			1.0													
Maximum Sorghum Diversion (DAS)						1.0										
Wheat Minimum Diversion (MDW)				1.0												
Wheat Maximum Diversion (DAW)					1.0											
Fallow (FAL)	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0									
Sorghum for Wheat (SFWL)								1.0								
Wheat for Sorghum (WFSL)									1.0							
Wheat for Barley (WFBL)										1.0						
Wheat for Rye (WFRL)											1.0					
Sorghum Certificate Limit (SPL)													1.0			
Wheat Certificate Limit (WCL)												1.0				
Wheat Production (WTPRD)																
Barley Production (BAPRD)																
Sorghum Production (SOPRD)																
Rye Production (RYPRD)																
Alfalfa Production (ALPRD)																
Nitrogen (NITRO)														-1.0		
Phosphorus (PHOSP)															-1.0	
Potassium (POTAS)																-1.0
Operating Capital (CAPIT)														.06	.06	.03
Annual Labor (LABOR)							.4									
January - April Labor (LABJA)							0									
May - July Labor (LABMJ)							.1									
August - September Labor (LABAS)							.2									
October - December (LABOD)							.1									
Native Pasture (PASTR)																
Wheat Pasture (WHTPT)																

TABLE XIII (CONTINUED)

	WHTB1	WHTB2	WHTB3	WHTU1	WHTU2	WHTU3	BARU2	BARU3	RYEB3	FGRU3	FGRB3	ALFB3	WHTSL	BARSL	RYESL	FGSEL	ALFSL	COWCF	SFSTR
Cost	9.50	9.50	9.50	9.50	9.50	9.50	9.00	9.00	9.50	7.00	7.00	48.00	-1.20	-.85	-1.60	-1.01	-30.00	-65.20	-31.00
(COPLD)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0							
(UPLD1)				1.0															
(UPLD2)					1.0		1.0												
(UPLD3)						1.0		1.0		1.0									
(BOTM1)	1.0																		
(BOTM2)		1.0																	
(BOTM3)			1.0						1.0		1.0	1.0							
(BALLT)							1.0												
(WTALT)	1.0	1.0	1.0	1.0	1.0	1.0													
(SOALT)										1.0	1.0								
(ORALT)									1.0										
(MDB)																			
(MDS)																			
(MDR)																			
(DAS)																			
(MDW)																			
(DAW)																			
(FAL)																			
(SFWL)																			
(WFSL)																			
(WFBL)																			
(WFRL)																			
(SPL)																			
(WCL)																			
(WTPRD)	-26	-24	-21	-24	-22	-20							1.0						
(BAPRD)							-24	-22						1.0					
(SOPRD)										-34	-36					1.0			
(RYPRD)									-30						1.0				
(ALPRD)												-6.0					1.0	.26	.15
(NITRO)	38	38	38	38	38	38													
(PHOSP)	22	22	22	22	22	22													
(POTAS)	8	8	8	8	8	8													
(CAPIT)	4.05	4.05	4.05	4.05	4.05	4.05	3.90	3.09	4.05	3.45	3.45	40.00						12.00	52.50
(LABOR)	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.78	1.78	4.0						8.0	1.0
(LABJA)	.12	.12	.12	.12	.12	.12	.12	.12	.12	.72	.72	0						4.5	.4
(LABMJ)	.95	.95	.95	.95	.95	.95	.95	.95	.95	.94	.94	2.56						.8	.1
(LABAS)	.58	.58	.58	.58	.58	.58	.58	.58	.58	.12	.12	1.45						.8	.1
(LABOD)	.18	.18	.18	.18	.18	.18	.18	.18	.18	0	0	0						1.9	.4
(PASTR)																		9.5	.2
(WHTPT)	-.7	-.7	-.7	-.7	-.7	-.7												2.5	2.2

TABLE XIV

DESCRIPTION OF COLUMN ABBREVIATIONS USED IN LINEAR PROGRAMMING MODEL FOR FARM II

MDBA	Minimum Diversion of Barley Allotment
MDSA	Minimum Diversion of Sorghum Allotment
MDRA	Minimum Diversion of Rye Allotment
MDWA	Minimum Diversion of Wheat Allotment
WDPAY	Wheat Diversion Payments
SDPAY	Sorghum Diversion Payments
FAL	Fallow
SFW	Sorghum Allotment for Wheat Allotment
WFS	Wheat Allotment for Sorghum Allotment
WFB	Wheat Allotment for Barley Allotment
WFOR	Wheat Allotment for Rye Allotment
WCA	Wheat Certificate Acreage
SCA	Feed Grain Certificate Acreage
N	Nitrogen
P	Phosphate
K	Potash
WHTB1	Wheat Bottomland #1
WHTB2	Wheat Bottomland #2
WHTB3	Wheat Bottomland #3
WHTU1	Wheat Upland #1
WHTU2	Wheat Upland #2
WHTU3	Wheat Upland #3
BARU2	Barley Upland #2
BARU3	Barley Upland #3
RYEB3	Rye Bottomland #3
FGRU3	Feed Grain Upland #3
FGRB3	Feed Grain Bottomland #3
ALFB3	Alfalfa Bottomland #3
COWCF	Cow-Calf Operation
SFSTR	Stocker-Feeder Steers
WHTSL	Wheat Sell
BARSL	Barley Sell
RYESL	Rye Sell
FGSEL	Feed Grain Sell
ALFSL	Alfalfa Sell

TABLE XV
OPTIMUM FARM PLAN AND FINANCIAL SUMMARY FOR GOVERNMENT PROGRAM ALTERNATIVE II ON FARM V

Part II Summary of the Optimum Farm Plan.
Alternative 2 Participation in Wheat Program Only

	Unit	Required	Amount
Crops			
Wheat 5PB (33-17-9)	Acre		40.0
Wheat 6PB (33-17-9)	Acre		16.0
Barley 6PR (33-17-9)	Acre		24.0
Barley 6A (33-17-9)	Acre		25.0
Other Land Usage			
Wheat Diversion Payment Acres	Acre		13.4
Minimum Diversion for Wheat	Acre		10.4
		Required	Excess
Labor	Hour	237.9	2762.1
January - April	Hour	12.6	287.4
May - July	Hour	99.75	700.25
August - September	Hour	60.9	439.1
October - December	Hour	18.9	381.1
Capital Available	Dollar		5000.00
Amount Used Adjusted to an annual basis	Dollar		951.60
Amount Not Used	Dollar		4048.40
Net Return to Land, Labor, Management and other Fixed Resources	Dollar		4115.70

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$2,457.60	Bu.	1.16	1.20	1.22
Barley	1,852.00	Bu.	.74	.80	.95
Government Payments					
Certificates	1,457.40				
Diversion	301.50				
Total	6,068.50				
Operating Expenses	1,386.00				
Fertilizer Expenses					
Nitrogen	343.20				
Phosphate	176.80				
Potash	46.80				
Total Expenses	1,952.80				
Net Return to Land Labor, Management and other Fixed Resources	$4,115.70				

TABLE XVI
OPTIMUM FARM PLAN AND FINANCIAL SUMMARY FOR GOVERNMENT PROGRAM ALTERNATIVE II ON FARM V AFTER ADDING 100 ACRES

Part II Summary of the Optimum Farm Plan

Alternative 2 Participation in Wheat Program Only

Crops	Unit		Amount
Wheat 5PB (33-17-9)	Acre		40.0
Wheat 6PB (33-17-9)	Acre		67.9
Barley 6PR (33-17-9)	Acre		72.1
Barley 5RB (33-17-9)	Acre		25.0
Barley 6A (33-17-9)	Acre		25.0
Other Land Usage			
Wheat Diversion Payment Acres	Acre		6.6
Minimum Diversion for Wheat	Acre		17.2
		Required	Excess
Labor	Hour	420.9	1579.1
January - April	Hour	27.5	272.5
May - July	Hour	217.55	582.45
August - September	Hour	132.8	367.2
October - December	Hour	41.2	358.8
Capital Available	Dollar		5000.00
Amount Used Adjusted to an annual basis	Dollar		1683.60
Amount Not Used	Dollar		3316.40
Net Return to Land, Labor, Management and other Fixed Resources	Dollar		6880.27

Part III Financial Summary

			Price Range		
Crop Sales		Unit	Lower Limit	Price Used	Upper Limit
Wheat	$4,512.84	Bu.	1.16	1.20	1.22
Barley	3,198.80	Bu.	.74	.80	.95
Government Payments					
Certificates	2,404.50				
Diversion	148.50				
Total	10,264.64				
Operating Expenses	2,381.57				
Fertilizer Expenses					
Nitrogen	607.20				
Phosphate	312.80				
Potash	82.80				
Total Expenses	3,384.37				
Net Return to Land, Labor, Management and other Fixed Resources	$6,880.27				

include the change in value resulting from inflation or deflation which occurs every year. A total of 100 acres is used as an example to be added to farming operation of farm IV. The different solutions are given in Tables XV and XVI taken from the optimum solution results given to the farmer of farm V.

The additional 100 acres yields a net return of $2,764.57 to the fixed resources. This value is the difference between the two net returns of Table XV and XVI. Table VII indicates the estimated fair market value of the 100 acres based upon varied capitalization rates.

TABLE XVII

MARKET VALUES OF LAND BASED ON VARIED CAPITALIZATION RATES AND NET RETURNS TO FIXED RESOURCES

Capitalization Rate	Net Returns	Market Value
6.0%	$2,764.57	$46,100
5.5%	2,764.57	50,250
5.0%	2,764.57	55,300
4.5%	2,764.57	61,400
4.0%	2,764.57	69,100

The capitalization rate is the assumed total rate required to induce a willing and able buyer to invest in the property. The rate is based on the estimated returns to comparable farms recently sold in the immediate locality. The capitalization rate is not necessarily equal to other investment rates of return. It is only the rate of return which buyers appear to be willing to accept, disregarding the increase in value due to inflation. The farmer of farm V can now choose which capitalization rate will induce him to purchase the additional 100 acres. The buyer of every sale has determined a lower capitalization rate than the other bidders whether or not he went through the same process.

CHAPTER IV

MINIMUM COST FERTILIZER BLENDING

The technique of linear programming is being applied to an increasing number of problems which involve quantitative aspects of blending problems. This chapter illustrates and describes the application of a linear programming technique that will provide a minimum cost fertilizer blend prepared by the dealer and sold to the farmer. Once the composition, cost and requirements for the fertilizers have been specified, a solution can be found for the minimum cost combination. Then the least cost fertilizer can be sold to the farmer. The retail price can reflect a savings to both the farmer and dealer.

The basic problem consists of mixing a formula containing nitrogen, phosphorus, or potassium. If each carrier considered in the mixing problem contained only nitrogen, phosphorus or potassium the several sources of one nutrient could be evaluated on the cost per pound and the least expensive source chosen. The same procedure could then be used for selecting the carriers of the other elements. The resulting mix would then be the least expensive one of all the carriers which contain only one element. But other mixtures may also be available. If the carriers contain more than one plant food, the minimum cost sources become more difficult to isolate. Then if requirements regarding the physical properties of the mix are added, the problem becomes even more complex.

Formulation charts are used by many fertilizer dealers to determine the least cost blend. The interpolation and calculation involved in the chart usage are very time consuming and approximate. If a price change occurs for certain fertilizers, the calculations must be done again.

In solving the minimum cost problem by a computer least cost analysis the least cost mix can be systematically selected and the specified requirements met. If the price of certain fertilizer grades change, as usually happens due to competition between dealers, the cost ranges can be observed to determine the range of least cost for the usage of a particular grade.

With the growing number of blending plants in Oklahoma, dealers have the facilities to mix a varied number of blended fertilizers. Actually the facilities that are needed only includes several blends of basic materials and a blender in which the material can be quickly loaded and made ready for application. Customers who have different needs for different crops and soils may choose several blends. The blends do not have to be in stock at all times. It is much more economical to store just the basic material to produce the needed blends.

Restrictions

The linear programming technique can be illustrated by using an example for a blending problem. Suppose a blender wants to make a ton of 12-24-24 mixed fertilizer.

Letting the quantities of the nine materials in Table XVII be designated as $x_i (i = 1, 2, 3, . . ., 9)$, the total quantity of mixed fertilizer produced is to be one ton: hence:

$$\sum_{i=1}^{9} x_i = 2,000 \text{ pounds}$$

The formula of the blend gives the other restrictions for the right hand side. In the example, the production of 12-24-24 mixed fertilizer

Table XVIII

Fertilizer Material Composition

Fertilizer Material (j)	Nitrogen (a_j)	Phosphate (b_j)	Potash (c_j)	Calcium (d_j)	Sulfur (e_j)
1. Ammonium Nitrate	33.5	00.0	00.0	00.0	00.0
2. Ammonium Phosphate	16.0	20.0	06.0	00.0	00.0
3. Ammonium Phos-Sulf	16.0	20.0	00.0	00.0	15.0
4. Diammonium Phosphate	18.0	46.0	00.0	00.0	00.0
5. Ammonium Sulfate	21.0	00.0	00.0	00.0	24.0
6. Superphos	00.0	20.0	00.0	00.0	12.0
7. Treple Superphos	00.0	46.0	00.0	00.0	00.0
8. Potash	00.0	00.0	60.0	00.0	00.0
9. Urea	41.4	00.0	00.0	00.0	00.0

required 240 pounds of nitrogen, 480 pounds of phosphate and 480 pounds of potash in the blend. The formula requirements may be written as follows:

$$\text{Nitrogen} \quad \sum_{j=1}^{9} a_j x_j = 240 \text{ pounds}$$

$$\text{Phosphate} \quad \sum_{j=1}^{9} b_j x_j = 480 \text{ pounds}$$

$$\text{Potash} \quad \sum_{j=1}^{9} c_j x_j = 480 \text{ pounds}$$

Price Considerations

The nutrient requirements can be satisfied by many combinations of the 9 fertilizers available to make the desired blend. The minimum cost linear programming method will isolate the single combination which minimizes ingredient cost. Now letting C'_j indicate the price per pound of each ingredient, the cost V, may be as follows:

$$V = \sum_{j=1}^{9} C'_j x_j$$

Now, the cost equation is minimized subject to the three restrictions.

Required Conditions

This mixing technique is applicable to any problem where the following conditions exist:

1. The objective is to minimize the cost of the blend.

2. Many different ingredients are available which are technically acceptable in a blend or mixture.

3. Characteristics of the ingredients are numerically measurable.

4. These are limits, either maximum, minimum or equalities, of the ingredient characteristics.

The required conditions may be indicated in the input form of Table XIX. Three types of problems may be solved by the least cost method.[1] The type I problem gives the percentage and cost of each material in the blend. In addition, the total cost per ton of the blend is given. Since the minimum cost program eliminates higher priced materials, a price at which the eliminated materials would come into the least cost blend is given. Therefore, if a price change of one of the materials not presently in the blend is made, the dealer can tell if the material would be used if it approaches or falls below this price, all other prices constant. An outgoing price is also listed for the materials in the blend. The

[1]Dr. Ted Nelson, Extension Economist at Oklahoma State University, originated the least cost blending format described here as a service to fertilizer dealers in Oklahoma.

TABLE XIX

FERTILIZER BLEND SUBMITTAL FORM

BASIC MATERIAL	COST PER TON	MINIMUM NITROGEN	MINIMUM PHOSP	MINIMUM POTASH	MINIMUM CALCIUM	MINIMUM SULFUR
210000 AMMONIUM SULFATE	__.__	21.00	0.00	0.00	0.00	24.00
340000 AMMO-NITRATE	__.__	33.50	0.00	0.00	0.00	0.00
460000 UREA	__.__	41.40	0.00	0.00	0.00	0.00
162000 AMM PHOS-SULF	__.__	16.00	20.00	0.00	0.00	15.00
184600 DIAMMONIUM PHOS	__.__	18.00	46.00	0.00	0.00	0.00
002100 SUPERPHOS	__.__	0.00	20.00	0.00	0.00	12.00
004600 TREPLE SUPERPHOS	__.__	0.00	46.00	0.00	0.00	0.00
000060 POTASH	__.__	0.00	0.00	60.00	0.00	0.00
062412 MIXD 6-24-12	__.__	6.00	24.00	12.00	0.00	0.00
102010 MIXD 10-20-10	__.__	10.00	20.00	10.00	0.00	0.00
122412 MIXD 12-24-12	__.__	12.00	24.00	12.00	0.00	0.00
142814 MIXD 14-28-14	__.__	14.00	28.00	14.00	0.00	0.00
162006 AMMONIUM PHOS	__.__	16.00	20.00	6.00	0.00	0.00
000000 LIME	__.__	0.00	0.00	0.00	100.00	0.00
______ ______________	__.__	__.__	__.__	__.__	__.__	__.__
______ ______________	__.__	__.__	__.__	__.__	__.__	__.__

Problem No.	Prob. Type	Acres	N	P_2O_5	K_2O	Ca	S
1.	______	______	__.__	__.__	__.__	__.__	__.__
2.	______	______	__.__	__.__	__.__	__.__	__.__
3.	______	______	__.__	__.__	__.__	__.__	__.__
4.	______	______	__.__	__.__	__.__	__.__	__.__

outgoing price indicates when another ingredient would be substituted for the present one in the blend.

The Type II problem contains the same results as the Type I problem, plus four additional factors. This second type gives the total amount of each material required for the mixture and the nitrogen, phosphorus and potassium percentages in the blend. The remaining three factors are the total cost of the mixture pounds to apply per acre and cost per acre to the dealer.

The Type III problem contains the same information as the Type I except the percentage of each material in the blend is the least cost combination for the ratio being requested. The requested blend may not be the least expensive ratio of the blend. A higher or lower analysis blend may be less expensive per pound of nutrient.

Output Summary

Table XX is an example of the table reprinted from the computerized program with particular prices chosen by the dealers. The cost per ton is the actual cost, except that a price of $99.00 per ton is assigned to the materials the dealer does not have or does not want to handle. The higher price excludes materials not desired from the blend.

Table XXI explains the results of a Type I problem for a 12-24-12 blend. The percent in mix column gives the percentage of the ingredient fertilizer used in making the blend. The next column indicates the cost of the ingredients per ton of the blend. The next two columns are used only for Type II problems in which a specified cost and total amount needed is associated with the acres to be fertilized. The assigned costs per ton column is listed again so that the incoming price column can be compared to it. This incoming price is the price to which the ingredient

TABLE XX

EXAMPLE OF FERTILIZER BLEND SUBMITTAL FORM

BASIC MATERIAL		COST PER TON	MINIMUM NITROGEN	MINIMUM PHOSP	MINIMUM POTASH	MINIMUM CALCIUM	MINIMUM SULFUR
210000	AMMONIUM SULFATE	99.00	21.00	0.00	0.00	0.00	24.00
340000	AMMO-NITRATE	42.00	33.50	0.00	0.00	0.00	0.00
460000	UREA	99.00	41.40	0.00	0.00	0.00	0.00
162000	AMM PHOS-SULF	99.00	16.00	20.00	0.00	0.00	15.00
184600	DIAMMONIUM PHOS	99.00	18.00	46.00	0.00	0.00	0.00
002100	SUPERPHOS	68.50	0.00	20.00	0.00	0.00	12.00
004600	TREPLE SUPERPHOS	31.70	0.00	46.00	0.00	0.00	0.00
000060	POTASH	56.30	0.00	0.00	60.00	0.00	0.00
062412	MIXD 6-24-12	29.50	6.00	24.00	12.00	0.00	0.00
102010	MIXD 10-20-12	99.00	10.00	20.00	10.00	0.00	0.00
122412	MIXD 12-24-12	99.00	12.00	24.00	12.00	0.00	0.00
142814	MIXD 14-28-14	99.00	14.00	28.00	14.00	0.00	0.00
162006	AMMONIUM PHOS	99.00	16.00	20.00	6.00	0.00	0.00
000000	LIME	6.00	0.00	0.00	0.00	100.00	0.00
______	______________	___.___	___.___	___.___	___.___	___.___	___.___
______	______________	___.___	___.___	___.___	___.___	___.___	___.___

Problem No.	Prob. Type	Acres	N	P_2O_5	K_2O	Ca	S
1.	1	______	12.___	24.___	24.___	___.___	___.___
2.	2	50	12.___	24.___	24.___	___.___	___.___
3.	3	______	12.___	24.___	24.___	___.___	___.___
4.	______	______	___.___	___.___	___.___	___.___	___.___

TABLE XXI

OUTPUT SUMMARY OF TYPE I PROBLEM

Ingredient	Percent In Mix	Cost Per Ton of Mix	For 0 Acres Total Needed	Total Cost	Assigned Cost/Ton	Incoming Price	Outgoing Price
210000 Ammonium Sulfate					99.00	28.57	
340000 Ammo-Nitrate	7.79	3.27			42.00	28.71	73.73
460000 Urea					99.00	55.43	
162000 Amm Phos-Sulf					99.00	41.96	
162006 Ammonium Phos					99.00	44.31	
184600 Diammonium Phos	52.17	35.74			68.50	25.34	75.64
002100 Superphos					31.70	24.76	
004600 Treple Superphos					56.30	49.16	
000060 Potash	40.00	11.00			29.50	6.00	227.51
102010 Mixd 10-20-10					99.00	39.43	
122412 Mixd 12-24-12					99.00	46.11	
142814 Mixd 14-28-14					99.00	52.80	
062412 Mixd 6-24-12					99.00	39.66	
000000 Lime	0.04	0.00			6.00	-110.76	14.68
Totals	100.00	50.81					

Nutrient specifications of this blend are as follows:

Ingredient	Percent In Mix	Forced Percentage	Pounds Per Acre	Nutrient Ratio	Cost Per Ton of Mix	Cost of One Percent Change
Nitrogen	12.00	12.00		1.00	12.90	1.07
Phosphorus	24.00	24.00		2.00	22.52	0.94
Potash	24.00	24.00		2.00	9.40	0.39
Calcium	0.00					
Sulfur	0.00					

must drop before it will be used in the desired blend. The outgoing price is given for the ingredients presently being used in making the blend. The outgoing is very helpful when a price change is made in the ingredients. As long as the present price is less than the outgoing price, the ingredient will be used to make the least cost blend. The nutrient specifications for the blend are at the bottom of each table.

The percentage in mix column indicates the nitrogen, phosphorus and potash percentage of the total blend. The forced percentage is the requested amount of each ingredient in a ton of the blend. The type II and Type III problem will possibly differ from the Type I because the force percentage may not be physically blended without using a filler such as lime. The Type I problem in Table XXI has a forced percentage of 12-24-24. But if the percentage was 12-24.01-24.01, lime would not have to be used in making the blend. Type II and III on Tables XXII and XXIII indicate the difference in the blends. By blending the requested ratio without lime, less total material per acre is needed to apply the same nutrients. Table XXII indicates that 99 pounds should be applied. The pounds per acre column is used only on Type II problems. The solution in Table XXII indicates that 12 pounds of nitrogen, 24 pounds of phosphorus and 24 pounds of potash should be applied.

The nutrient ratio is the smallest numerical quotient that can be derived from the requested ratio. The cost per ton of mix indicates the price of nitrogen, phosphorus and potash for every ton blended. The cost of a one percent change in the blend is given to determine the additional cost involved to increase the nutrient content.

Table XXII is an output summary for a Type II problem in which 50 acres is to be fertilized. This type of problem gives the amount to apply and cost per acre. The solution indicates that 99 pounds per acre should

TABLE XXII

OUTPUT SUMMARY OF TYPE II PROBLEM

Ingredient	Percent In Mix	Cost Per Ton of Mix	For 50 Acres Total Needed	For 50 Acres Total Cost	Assigned Cost/Ton	Incoming Price	Outgoing Price
210000 Ammonium Sulfate					99.00	26.33	
340000 Ammo-Nitrate	7.79	3.27	0.19	8.18	42.00	22.71	72.10
460000 Urea					99.00	57.67	
162000 Amm Phos-Sulf					99.00	40.03	
162000 Ammonium Phos					99.00	42.98	
184600 Diammonium Phos	52.19	35.75	1.30	89.35	68.50	22.57	78.87
002100 Superphos					31.70	19.97	
004600 Treple Superphos					56.30	45.93	
000060 Potash	40.02	11.80	1.00	29.50	29.50	0.00	229.24
102010 Mixd 10-20-10					99.00	37.42	
122412 Mixd 12-24-12					99.00	44.91	
142814 Mixd 14-28-14					99.00	52.39	
062412 Mixd 6-24-12					99.00	37.39	
000000 Lime					6.00	0.00	
Totals	100.00	$ 50.83	2.4990	$127.02			

Apply 99 pounds per acre at $ 50.83/Ton = $ 2.54 per acre.

Nutrient Specifications of this blend are as follows:

Ingredient	Percent In Mix	Forced Percentage	Pounds Per Acre	Nutrient Ratio	Cost Per Ton of Mix	Cost of One Percent Change
Nitrogen	12.00	12.00	12.00	1.00	15.05	1.25
Phosphorus	24.01	24.01	24.00	2.00	23.97	1.00
Potash	24.01	24.01	24.00	2.00	11.80	0.49
Calcium	0.00					
Sulfur	0.00					

TABLE XXIII

OUTPUT SUMMARY OF TYPE III PROBLEM

Ingredient	Percent In Mix	Cost Per Ton of Mix	For 0 Acres Total Needed	Total Cost	Assigned Cost/Ton	Incoming Price	Outgoing Price
210000 Ammonium Sulfate					99.00	26.33	
340000 Ammo-Nitrate	7.79	3.27			42.00	22.71	72.10
460000 Urea					99.00	57.67	
162000 Amm Phos-Sulf					99.00	40.03	
162006 Ammonium Phos					99.00	42.98	
184600 Diammonium Phos	52.19	35.75			68.50	22.57	78.87
002100 Superphos					31.70	19.97	
004600 Treple Superphos					56.30	45.93	
000060 Potash	40.02	11.80			29.50	0.00	229.24
102010 Mixd 10-20-10					99.00	37.42	
122412 Mixd 12-24-12					99.00	44.91	
142814 Mixd 14-28-14					99.00	52.39	
062412 Mixd 6-24-12					99.00	37.39	
000000 Lime					6.00	0.00	
Totals	100.00	50.83					

Nutrient Specifications of this Blend are as follows:

Ingredient	Percent In Mix	Forced Percentage	Pounds Per Acre	Nutrient Ratio	Cost Per Ton of Mix	Cost of One Percent Change
Nitrogen	12.00	12.00		1.00	15.05	1.25
Phosphorus	24.01	24.01		2.00	23.97	1.00
Potash	24.01	24.01		2.00	11.80	0.49
Calcium	0.00					
Sulfur	0.00					

be applied at a cost to the dealer at $50.83 per ton or $2.54 per acre. Table XXIII is similar to the Type I output, except the percentage shown is the least cost combination for the requested ratio.

Results of Least Cost Fertilizer Blending

The three cooperating fertilizer dealers eagerly utilized the computerized least cost blending service. In fact, an average of four different groups of problems was solved per dealer during the fall fertilizer season. Because of the competitiveness of the fertilizer business, the prices of the fertilizers used in blending kept changing during the application season. Therefore, each time there was a significant price change, the percentage of certain ingredients and the cost per ton changed for each blend. The dealer would then immediately have to determine what ingredients to use in making the blend and determine the new price. The dealers formerly calculated the blends by hand. The computerized solutions were correct for every example that was checked. However, several mistakes were made by the dealers making the hand calculations.

There are numerous advantages to the computerized least cost blending service as outlined by the dealers. One advantage is the amount of time spent calculating the requirements of the blends. One dealer commented that the service would save him at least six hours per week during the fertilizer application season. Another advantage would be the security involved in making the desired blend wanted by the farmer at least cost. Still another advantage would be to know that the formula for the blend was correct. This was a major worry of the cooperating dealers. The fertilizer blend is checked by the state board of agriculture for the nutrient elements supposedly in the blend. A penalty is enforced if the blend does not contain the nutrients specified by the farmer.

The information required from the dealer to determine the desired blends is easily prepared. The dealer gives the prices of the available ingredients, the nutrient requirements and the type of problem desired. This information can be mailed or telephoned to a central receiving station for use in the computer program. Results can be telephoned to the dealer and the detailed output mailed for later delivery. The time involved for the telephone service will depend upon the number of program changes and the required computer time. The telephone service worked very effectively in this experiment.

In conclusion, all three dealers wanted to use the service in the future. One dealer commented that the computerized least cost blending would allow him more time for management of the business during his busiest period.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were (1) to develop a farm programming technique that fertilizer dealers could use with their farmer customers, (2) to test the programming device on actual farm organizations with cooperating farmers and fertilizer dealers and (3) to involve the cooperating dealers in an educational program to increase their knowledge of economics involved in organizing a farm.

A linear programming technique was designed to help farmers plan their farm organization to maximize net returns to land, labor, management and other fixed resources for the next crop year. Considered in the linear program were wheat and feed grain program alternatives and crop and livestock enterprises.

A second linear programming technique was designed to determine the least cost blending ingredients for various fertilizer analyses required by farmers.

The farm programming technique was tested on seven farm organizations in North Central Oklahoma to determine the technical feasibility of the technique becoming a service extended by fertilizer dealers to their farmer customers. The farm programming service was organized to help the farmer and his fertilizer dealer develop and collect the information required to determine the optimum farm plan. Then, the future development of the input information could be accomplished by the conjunctive efforts of the farmer and his fertilizer dealer. The purpose of the programming service is to maximize net returns to land, labor, management and other fixed resources.

Three cooperating fertilizer dealers in North Central Oklahoma tested the least cost blending technique. The basic problem consisted of mixing a formula containing nitrogen, phosphorus, or potassium. There are three types of problems which can be solved by the least cost computer service which were discussed in Chapter IV. The Type I problem gives the percentage and cost of each material in the blend. In addition, the total cost per ton of the blend is given. The Type II problem contains the same results as the Type I problem, plus four additional factors. This second type gives the total amount of each material required for the mixture and the nitrogen, phosphorus and potassium percentages in the blend. The remaining two factors are the total cost of the mix and the amount to apply and the cost per acre to the dealer. The Type III problem contains the same information as the Type I except the percentage of each material in the blend is the least cost combination for the ratio being requested.

To fulfill the educational program objective, a workshop was organized to acquaint the fertilizer dealers with various topics pertaining to the economic importances of an optimum farm organization and their fertilizer business. Also in this thesis, possible fertilizer recommendation procedures are outlined. The procedures are the same that agronomists and soil scientists use in making recommendations.

CONCLUSIONS

The farm programming service and the least cost blending service were very effective in fulfilling their designed purposes. The computerized farm programming service requires the greatest amount of time and preparation to develop a meaningful set of results for the farmer. But, if the service is used for the second year, the computer program would have few major changes.

The computerized farm programming service determined the government program and crop alternatives that would yield the highest net return to land, labor, management and other fixed resources for each farmer and his organization.

The computer service results had three characteristics which were of great interest to the farmer cooperators. The first was the analysis made of each government program and how each would affect the net returns. The farmers were very interested in changes that were needed among the present enterprises to increase net returns. The final characteristic was how the net returns could be maximized from single enterprises. Farmers would have been very interested in knowing the optimum fertilizer rates to produce maximum net returns to land, labor, management and other fixed resources. But due to the lack of crop response information, the farm programming service was inadequate for making fertilizer rate recommendations. Farmers had not experimented with different fertilizer rates to determine the change in yields; therefore, few fertilizer rate alternatives could be inserted into the linear program.

The least cost blending service for the fertilizer dealers was very successful. The price of the nutrients to be blended, nutrient requirements of the mixture and the type of problem to be solved is all that is needed for the computer program. Thus, it would be relatively simple to establish this service.

NEED FOR FURTHER STUDY

The need for a farm programming service will increase in the future. Every farmer needs to examine the whole farm organization every year to determine what changes would give him a higher return to his investment. The collection of input data for the farmer and dealer to complete needs to be as simple as possible. Then the information can be complied and inserted into the computer program.

Additional research is also needed to add the farm programming service to one of a large number of different record keeping systems used today. If the record keeping systems could be added to the farm organization service, a farmer would certainly be better informed about his farm organization.

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APPENDIX

FACTORS WHICH INFLUENCE FERTILIZER RECOMMENDATIONS

Basically, five factors influence fertilizer recommendations according to Baumann.[1]

1. Accurate Soil Tests

Soil fertility level can be indicated by soil tests which have been correlated with response to fertilizer on Oklahoma soils through field and greenhouse research. Soil tests must be accurate, but the best test can be no better than the sample that is tested.

To get a good soil test, there must be one or more soil samples that are representative of the area to be fertilized. This can be accomplished by taking a composite soil sample from numerous spots over the field.

2. Soil Characteristics and Production Capacity

A knowledge of soil is essential in order to make correct fertilizer recommendations. Effective interpretation of soil tests is partially dependent upon the texture, the soil depth, and the characteristics of the subsoil. For example, the fertilizer recommendations would not be the same in a deep soil as on a shallow soil, although the soil tests might be identical.

A deep, moderately permeable to permeable soil generally has excellent soil, moisture, and plant root relationship. Such soil can effectively and economically utilize a heavy-fertilizer application.

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[1]W. Elmo Baumann, "Fertilizer and Lime Recommendations for Oklahoma," Oklahoma State Extension Service, pp. 3-6.

Soils having a claypan, which restricts movements of moisture, roots, and air, usually will not respond to fertilizer treatment as well as a permeable soil.

3. Past Use and Treatment

Fertilizer recommendations are greatly improved if more information than a soil test is available. They are strengthened by knowledge of the previous crops, history of yields, fertilization, and lime use, and management practices.

4. Crop Planned and Climatic Yield Probabilities

Crops vary considerably in their requirements for various plant nutrients. Crops grown primarily for forage usually have different fertility requirements than those grown for grain. Most of the important cash crops will give profitable returns, even though they are grown on deficient soils, if fertilizers are used properly.

The relative cash value of the crop will influence the amount of fertilizer than can be used profitably. In Oklahoma, the amount and distribution of rainfall are important factors governing crop yields and in the plant's inability to utilize the applied plant nutrients. A crop under irrigation has higher fertility requirements than one under dryland conditions. Irrigated crops were not included in this study, with the exception of one farm in which milo corn silage were grown.

5. Farmers' Desires and Resources

In many cases, the desires and wishes of the farm operator have an important bearing on fertilizer recommendations. This does not imply that fertilizer recommendations should be made to fit what the farmer wants to use rather than what is actually needed for a particular field or crop.

Some farmers may wish to apply fertilizer at the maximum possible profitable rate with an idea of greatest potential returns. They do this with the full understanding that if weather conditions prevent maximum yields, some of the remaining fertilizer will be left for the production of later crops.

Theoretical Recommendation Procedures

Soil tests have been the basis for making fertilizer recommendations to farmers for many years. This is actually the starting point for nearly all state extension and experiment station fertilizer recommendations through out the United States.

The following is the procedure used in making individual farm fertilizer recommendations from the soil tests.

(1) Primary nutrient requirements for the desired crop and yield levels are established.

(2) The quantities of available nutrients in the soil are measured.

(3) The nutrient quantities measured in the soil are subtracted from the nutrient requirements for the crop and yield goal which the farmer desires.

(4) If the nutrient requirements exceed those available for the soil the difference is the amount of fertilizer which is recommended.

Upon examination of this procedure, there exist two basic data needs: (1) nutrient requirements by crop and yield level and (2) reliable soil test measurements. However, the data requirements are not obtained simply. Because the problem compounds when the concept of nutrient fixation and availability is introduced, not all of the nutrients measured by the soil tests are available for uptake into the plant system. Neither is the entire quantity of nutrients applied as fertilizer completely available to the crops. Consequently, these two sources must be adjusted to reflect the quantities of nutrients actually available to meet the plant nutrient demand.

Another agronomic method for recommended fertilizer rates can be developed by determining the yield possibility. The yield possibility will vary from year to year. It will depend on the climatic conditions for the year being analyzed and making the assumption that all the plant nutrients are available in adequate but not harmful amounts.

The availability of phosphorus and potassium depends on the root system of the plant which in turn depends on the available moisture. In Oklahoma, phosphorus and potassium are immobile once in the soil. Therefore, sufficiency can be calculated on a percentage basis for phosphorus and multiplied times the original yield possibility to determine the reduced yield due to reduction in availability of phosphorus. If availability of potassium is less than 100 percent, then a further decrease in yield possibility can be calculated from the phosphorus derived yield possibility.

When the final yield possibility is found, the nitrogen rate can then be derived by approximating the final yield possibility from the decrease of availability found in the use of phosphorus and potassium.

A Mitscherlich type equation can also be used to determine the application rate of phosphorus or potassium.

$$\log (A-Y) = \log A + CX - bX'$$

A = yield obtained

Y = yield possibility

C = soil test value

X = fertilizer in soil

b = fertilizer coefficient

X' = fertilizer level

The assumption must be made that yield possibility is equal to yield obtained ($A = Y$). Solving for X' will give the recommended fertilizer level. It must be emphasized that this method is only for the potassium and phosphorus recommendation.

Classic Production Models

There are two classic models which can be used in the description of a product output from the factor inputs.

The Liebig model describes production in terms of limiting factors. It is most suitable for the mobile nutrients. Production is assumed to increase at a constant rate with respect to each nutrient until one of the nutrients becomes limiting or some maximum yield is attained which is a function of exogenous factors. These factors might include variety, seeding rate, or moisture, to name a few.

The Liebig model can be denoted in a two nutrient situation.

(1) $X_1 \geq a_1 y = z_1$

(2) $X_2 \geq a_2 y = z_2$

(3) $m \geq y$

X_1 = amount of nutrient 1 present in the soil and available for plant use.

X_2 = amount of nutrient 2 present in the soil and available for plant use.

a_1 = required amount of nutrient 1 for the maximum yield.

a_2 = required amount of nutrient 2 for the maximum yield.

z_1 = amount of nutrient 1 that must be added to quantity in the soil.

z_2 = amount of nutrient 2 that must be added to quantity in the soil.

m = ceiling on yield.

y = yield.

The nutrients are independent in the Liebig Model and do not allow nutrient substitution.

The Mitscherlich-Spillman model is much more suitable because substitution of nutrients is permitted and is best for immobile nutrients. The following equation is of the two nutrient case.

$$Y = A \left[1 - R^{Z_1 + X_1}\right]\left[1 - R^{Z_2 + X_2}\right]$$

Y = Yield

A = maximum yield of all factors

R = ratio which marginal productivity declines

Z_1 = quantity of nutrient 1 in soil

Z_2 = quantity of nutrient 2 in soil

X_1 = quantity of Z_1 applied as fertilizer

X_2 = quantity of Z_2 applied as fertilizer

The Mitscherlich-Spillman model requires that the level of other nutrients be known before recommendations can be made for any specific nutrient in that nutrient substitution can occur. Since other nutrient level requirements are known, this requires a solution to a set of simultaneous equations. The data requirements are much more rigorous for this model since the values in the equations cannot be estimated independently.

If the production relationship is a unilateral casual relation with output dependent upon a number of predetermined input variables, the single equation model is certainly appropriate. Therefore, the best estimates of the production function parameters can be determined by the least squares multiple regression procedure. However, as formerly indicated, the nutrient levels of the Mitscherlich-Spillman model must be mutually determined variables. The biological and physical logic relevant to this production process indicates that the parameters of the production relationship should be estimated in terms of the complete set of simultaneous equations in which the production relation is embedded.[2]

The modification consists of treating nutrient requirements as dependent upon yield level. This approximates diminishing returns to each of the three primary nutrients.

Model:

$$b_N \geq a_{11} y_1 + a_{12} y_2 + \ldots + a_{1n} y_n - N$$

$$b_P \geq a_{21} y_1 + a_{22} y_2 + \ldots + a_{2n} y_n - P$$

$$b_K \geq a_{31} y_1 + a_{32} y_2 + \ldots + a_{3n} y_n - K$$

$$m \geq y_1 + y_2 + \ldots + y_n$$

subject to:

$$a_{11} \leq a_{12} \ldots \leq a_{1n}$$

$$a_{21} \leq a_{22} \ldots \leq a_{2n}$$

$$a_{31} \leq a_{32} \ldots \leq a_{3n}$$

y = yield

b_N = available nitrogen in soil

b_P = available phosphorus in soil

b_K = available potassium in soil

a_{1j} = nitrogen requirement per unit of y_j

a_{2j} = phosphorus requirement per unit of y_j

[2]Earl O. Heady and John L. Dillon, Agricultural Production Functions, Iowa State University Press, Ames, Iowa, 1961, p. 138.

a_{3j} = potassium requirement per unit of y_j

M = maximum yield

N = nitrogen fertilizer

P = phosphorus fertilizer

K = potassium fertilizer

Upon inspection of this simultaneous equation, there are three requirements of data. These would include:

(1) Quantity of nutrients already in the soil.

(2) Nutrient requirements for respective yields.

(3) Maximum yield obtainable imposed by nonnutrient factors.

This is the only treatment of production functions by simultaneous equations that will be included in this thesis. The single equation production function will be the only type used.

Nutrient Content of Soil

To establish a standard for a base it is necessary to prescribe the chemical tests used to measure the nutrient content of the soil.

Nitrogen is based on organic matter tests by the percent of the soil's weight.

$$N = \frac{\frac{2,000,000}{2} X_1}{10} X_2$$

N = available nitrogen per acre

X_1 = percent of organic matter

X_2 = nitrogen release rate expressed in a percentage.

The constant 2,000,000 represents the pounds of soil in the plow layer or top seven inches of top soil. Division of the pounds of organic matter per acre by two is based on the assumption that organic matter is composed of 50 percent carbon. The constant of 10 is based upon as assumed carbon-nitrogen ratio of 10:1.

The organic matter percentage is taken directly from the soil test. However, the active nitrogen release rate from the total nitrogen is a function of soil type. In Oklahoma, the clay soils release about .5 percent, silt loam soils one percent and sandy soils release about two percent of the nitrogen.

The Oklahoma County extension laboratories use a colorimetric method of measuring soil organic matter determined by the wet oxidation procedure.[3] Upon determining a colorimetric reading an organic matter conversion chart is used to determine percent of organic matter. The colorimetric reading is recorded and the adjective reading is given from the conversion table.

The crop yield and fertilizer history are analyzed to determine the recommended rate of application for the crop that is to be planted.

There are two tests now used in Oklahoma for the phosphate test. The county extension laboratories use the colorimetric method for measuring the inorganic phosphorus which is soluble in dilute sulphuric acid. The H_2SO_4 extractant is soon to be replaced by the Bray P_1 test for available phosphorus. Conversion tables are again used in determining the adjective reading for the soil test. The recommended application rate is checked against rates and responses of field plots in the general area.

There is a small lack of knowledge of the farmer in the conversion equation of phosphorus to its phosphate equivalent. The equation depends only on the elemental weights of the elements involved.

This equation converts the phosphorus measurement to its phosphate equivalent.

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[3]Elmo W. Baumann., "County Soil Testing Laboratory Procedures for Oklahoma," Oklahoma State Extension Service, p. 7.

$P_2O_5 = (X_1)\ (2.2912)$

P_2O_5 = pounds of available phosphate per acre

X_1 = pounds of available phosphorus per acre based on Bray P_1 test.

There are two available extractant tests for potash. The county extension laboratories use a turbidimetric method of measuring available potassium. Another test is the flame photometer test for available potassium. The county extension laboratories use a conversion table to convert the readings found over to the adjective rating.

This equation converts available potassium to its available potash equivalent.

$K_2O = (X_1)\ (1.2046)$

K_2O = pounds of available potash per acre

X_1 = pounds available per acre based on test.

Factors that Influence Fertilizer Recommendations

The average annual rainfall in Oklahoma ranges from a high of 50 inches in the southeastern part of the state to less than 16 inches in the Panhandle. Fluctuation from this normal rainfall is very common. Oklahoma's climate is characterized by frequent drought periods of three to six weeks or more. These erratic climate conditions, along with wide variations in soil characteristics, fertility level, and past management systems, increase the difficulty of making correct fertility recommendations.

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