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ADJUSTMENT IN THE UTILIZATION OF AGRICULTURAL LAND IN SOUTH CENTRAL MICHIGAN WITH SPECIAL EMPHASIS ON CASH-GRAIN FARMS

By

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ABSTRACT

ADJUSTMENT IN THE UTILIZATION OF AGRICULTURAL LAND IN SOUTH CENTRAL MICHIGAN WITH SPECIAL EMPHASIS ON CASH-GRAIN FARMS

By

Yung-chang Lee

The main objective of this study was to determine profitable adjustments in the organization and use of land by cash-grain farms in response to the increasing demand for agricultural products. Emphasis was placed on estimation of the marginal value productivities for various inputs and investments which would provide an objective and reliable basis for evaluating the efficiency of current farm organizations and serve as a guide in planning the necessary changes in farm organization. Further, the general land use situation and the factors affecting the utilization of land in a Miami/Conover soil area were studied.

The data used in this study were obtained from 61 cash grain farms in south central Michigan for the operating year 1972.

Linear programming was used to determine optimum farm plans with (1) farm resources fixed at initial level, (2)

labor, land and machinery investment variable and (3) product prices variable. Investment/disinvestment theory was incorporated into situations (2) and (3). Farmers were stratified by age of operator and net worth as a major determinant for setting up four representative farms. The former was used to indicate their willingness and the latter their ability to make adjustments. The analysis was first presented for Model I with cropland and associated durable resources fixed at initial levels. Secondly, the optimal organization was given for Model II which permitted variation in land resources and associated durable assets.

A production function of the Cobb-Douglas type was employed in deriving the estimates of marginal value productivities of inputs and investments. An effort was made to examine returns to scale by dividing the sample farms into two size groups. Examination of results lead to use of the third equation which forced constant returns to scale. Estimated coefficients were adjusted in a rough "Bayesian" way. Profitable reorganizations of farms were studied using the adjusted regression coefficients.

A comparison of linear programming and Cobb-Douglas techniques was made so as to be able to exploit fully their complementarities. In addition, an attempt was made to distinguish the more or less pseudo MVPs of linear programming from the MVPs of continuous function, which are partial derivatives of such functions.

The programmed solutions indicated that farms in this area similar to the representative cash-grain farms could profitably adopt a wheat-beans rotation under price conditions which existed in late 1973. Also, a corn-corn-corn-corn-soybeans rotation entered the optimal solution on larger farms. Land was the most limiting resource for each representative farm, so long as off farm work and migration were restricted. All farms had some members with off farm work, which agrees with what cash grain farmers were doing in south central Michigan area in 1973. Maximization of returns for representative farms in the studied area used all initial capital and considerable credit indicating that cash grain farmers are currently not fully utilizing their capital resources. Furthermore, capital and labor were not fully utilized in Model I where farm resources were fixed at initial levels. Thus, the representative farms studied were not completely organized so as to maximize profits.

The results of the functional analysis showed that marginal value product for land was comparatively high, indicating the desirability of a moderate expansion in acreage per farm. Operating expenditures and machinery investments were high relative to the other inputs, as reflected by the low returns to these input categories. This suggests that (a) more care is needed in handling operating expenses and machinery investment, and (b) the need to expand farm size in order to use machinery and operating expenditures more effectively. The earning power of farm labor was still not high enough to compete with industrial wage rates even at favorable 1973 farm product prices. Thus, off farm work and/or migration was justified. The low earning power of labor indicated the desirability of reducing its use relative to land and other inputs.

An increase in the use of land would tend to reduce its earning power at the margin but at the same time would increase the marginal earnings of machinery, operating expenditures and labor. Consequently, higher farm income would be generated due to better farm resource combination involving more land relative to machinery and, especially, labor. Near constant returns to scale beyond 150 tillable acres were found empirically in the functional analysis, but were assumed in the linear program; thus findings of the functional analysis confirm the assumptions of the linear programming analysis. Both functional and programming analyses indicated high returns to land and low returns to other inputs and investments.

The implications of the study were drawn in such a way as to exploit the complementarities between the linear programming and Cobb-Douglas analyses. Judging from the existence of considerable amounts of unused cropland and potential cropland found in the area studied and the fairly high returns to land, it was concluded moderate increases in farm size should be expected to continue in a foreseeable future. The continued development and rapid adoption of larger and efficient machinery will probably give additional momentum to this trend, and creates some pressure on land prices.

However, farm size should not be expected to expand without limit. The programmed results indicated that labor (including managerial labor) is a major restriction on expansion of farm size. In addition, the trend toward increasing farm size would be offset by continual increasing inputs costs for machinery, fuel, herbicides, labor, and fertilizer etc.; reduced availability of both skilled labor and entrepreneurs; and product price uncertainty.

The results of the study imply that the possibility of establishing new farms is low due to: (1) the cost involved in establishing a new farm, (2) low returns to labor, cash expenditures and machinery even at 1973 farm product prices, (3) the scattered location of unused land, and (4) nonexistence of economies to scale beyond 150 tillable acres. As such, a continual decrease in the number of farms would be expected, as average farm size becomes larger and more efficient, larger machinery is substituted for increasingly expensive labor in the production process.

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Any errors in this manuscript are the responsibility of the author.

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CHAPTER I

INTRODUCTION

Farmers in Michigan as well as farmers in the rest of the world have been facing a problem of adjustment in the use of production resources due to an ever changing prices, institutions, technology and people. As a result, farms have been changing rapidly in resource usage and in structure. Average farm size is becoming larger and more capital has been substituted for labor in the production process as agricultural wages increase. Some farmers have become part-time farmers or rural residents while renting or idling part of their farmland. Others are altering their resource use to enterprises requiring new and different skills and equipment with some uncertainties.

This adjustment problem on the part of the individual farmer has been aggravated recently as the demand for many agricultural products, both domestic and abroad, has increased significantly. The demand for agricultural products is expected to increase further in the future. This coupled with the exhaustion of government stocks of feed grains causes agricultural economists and policy makers to seek ways to increase agricultural production to meet the new demands.

One of the several possible ways to increase agricultural production would be to bring more cropland into cultivation. This research is designed to investigate (1) the possible economic adjustments related to increased land utilization in response to the increase in product prices and (2) the possibilities of increasing agricultural production through crop acreage expansion at the farm level.

Statement of the Problem

It has long been recognized that there has been overinvestment in the agricultural sector in the United States. The overinvestment in the sector has resulted in supplying an abundance of cheap food to consumers, on the one hand, and the incurring of a capital loss for farmers, on the other.[1]

Two problems loom large at this juncture. One has been the failure of marginal returns to capital, land and labor to cover their acquisition cost and, the other, low income levels in the agricultural sector relative to those in the nonagricultural sector. While the marginal value products of labor and land have been lower than those in the nonagricultural sector, it does not always pay farmers to migrate or disinvest because of high moving and liquidation costs. Though a large out-migration of young agricultural

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[1]Johnson, Glenn L., and Quance, Leroy, The Overproduction Trap in U.S. Agriculture, (Baltimore: The Johns Hopkins University Press, 1972) p. 3.

labor has taken place, the marginal value product of farm labor has tended to equalize with the low salvage wage rate of middle-aged farmers lacking industrial skills and without labor union seniority.

The marginal value product of farm land, on the other hand, has been so low that some central Michigan farm land has been abandoned for farming and some crop land has been diverted by government production control programs. The result until recently has been the prevalence of excess production capacity, low earnings in farming, high cost of government programs and economic instability in the agricultural sector. These are symptoms of excess resources.

Since the middle of 1972, however, the demand for agricultural products has increased rapidly and since current production plus carryover stocks were less than this demand, the prices of farm products have increased rapidly. This significant increase in the demand for agricultural products, both abroad and domestically, gives rise to problems of adjustment in the agricultural sector. Among these, the problem of more efficiently utilizing farm land to satisfy expanded demand has received increasing recent attention. Many agricultural economists, as well as policy makers, have been seeking ways to expand agricultural production to alleviate the rapid increase in food prices.

Conceptually, there are three possibilities to increase food, roughage, and feed grain production. Firstly, more farm products could be produced by reallocation of cropland, i.e., through the regional and farm to farm specialization. Another solution is to increase yields from present cropland through more intensive cultivation. Lastly, food production could be increased by bringing more cropland into production.

Unoperated tillable land can be pulled into production if there is sufficient economic justification. The question is how high farm product prices have to be in order to give incentive to farmers to bring presently unused land into production with increasing costs for machinery, energy and labor. The cost of bringing unused land into production bears on the feasibility of cultivating land now unused.

Farmers are encountering many perplexing problems due to rapidly changing demand conditions. Some of the relevant questions are: (1) what are some of the possible economic adjustments related to land utilization? (2) what are the key factors that limit the utilization of more agricultural land? (3) how do farmers respond to changing demand conditions and government programs? e.g., how much unused crop land can come into production if the set-aside program is eliminated and if prices stay high? (4) what are the effects of price changes on land utilization and operation of the farm--more specifically, to what extent must output price rise in order to bring unoperated cropland back into production? (5) how long are favorable prices likely to persist?

With the recent expansion in demand for agricultural products, the series of questions listed above becomes extremely important and they need to be answered in order to assist in planning on the part of participants in the farm sector and to assist in developing relevant public policy for the sector. The present investigation attempts to answer some of the above mentioned questions.

Objectives of the Study

In response to the problem identified above, the objectives of this study are as follows:

1. To determine the profit-maximizing organizations by using linear programming techniques on representative farms in this selected area, and further to examine the competitive position of alternative crop rotations covered in the model.
2. To determine the effect on gross margin, resulting optimum organization and changes of crop rotations caused by variations in the levels of land resource availability.
3. To provide information about the probable effect of product prices on land utilization and operation of the farm under 1973 price relationship.
4. To estimate the marginal revenue productivity of the resources as presently utilized under 1972 price relationship and to determine the implication of those estimates for cash grain farms in south-central Michigan.

5. To identify the main factors limiting the utilization of more agricultural land and to estimate potential land supplies in the Miami/Conover soils of a selected area in south-central Michigan.
6. To determine policy implications and consequences for alternative ways of organizing the use of Miami/Conover soils.

Since linear programming and Cobb-Douglas function are employed in this study, emphasis is placed on a comparison of these two techniques, so as to be able to exploit fully their complementarities.

Furthermore, an attempt will also be made to distinguish the more or less pseudo MVPs of linear programming from the true MVPs of continuous function which are partial derivatives of such functions.

Organization of the Thesis

Chapter II is devoted to the discussion of methodology. The research procedures, sources of data, the sample and defining representative farm are main topics in this chapter. The analytical model used to determine the best combination of enterprise and land use is discussed in Chapter III. Also a comparision of the linear programming and Cobb-Douglas analyses is presented.

Chapter IV discusses optimum farm organizations and land use for the four representative farms. Chapter V is devoted to the procedures used in deriving estimates of regression coefficients and value productivity of input categories. In Chatper VI projected consequences of alternative ways of organizing the use of Miami/Conover soils in south-central Michigan are presented. In this chapter, the agricultural land utilization, factors limiting the utilization of more agricultural land, and the estimation of potential land supplies in the Miami/Conover soils are discussed. Chapter VII provides a summary of findings drawn from both the linear programming and functional analyses. The results of the land utilization survey, implications deriving from the body of the thesis and areas for future research are also presented.

CHAPTER II

METHODOLOGY

The analytical techniques employed in this study involve the use of linear programming analysis and Cobb-Douglas analysis. As the cost of programming each farm would be prohibitive, it is necessary to define representative farms in carrying out the linear programming analysis.

The procedures involved in carrying out the study include: (1) surveying cash grain farms located on Miami/Conover soils in a selected area in south-central Michigan; (2) using the data collected in the field survey to define four representative farms in terms of net worth and operator's age; (3) constructing a linear program for each of the representative farms; (4) specifying assumptions about input and output prices; (5) evaluating the result of the study and (6) estimating the productivities of resources from the data collected in the field survey by fitting and analyzing Cobb-Douglas function.

The linear programming analysis in this study will be carried out under the following situations: (1) farm resources fixed at initial level; (2) land, labor resources and machinery investment variable and (3) prices variable. Investment/disinvestment theory will be used in analyzing situation (2) and (3) in such a way as to determine endogenously whether resources are fixed or subject to investment and disinvestment.

The investment/disinvestment theory[1] used states that an asset or resource becomes fixed when marginal value product of the resource is bounded by the acquisition costs and salvage or disposal values of the resource. When the marginal value product of the resource is less than its disposal price, it is profitable to disinvest. On the other hand, when marginal value product of the resource is larger than its acquisition price, it is profitable to invest.

By incorporating this theory in the linear programming model it determines an activity where the resource restrictions can be endogenously rather than exogenously determined. It should be realized that the conception of this model would not be useful for a particular firm situation where all resources with $Px_{iA} > Px_{iS}$ are known ahead of time to have $Px_{iS} \leq MVPx_i \leq Px_{iA}$ for all possible reorganizations.[2]

Sources of Data

Since linear programming and functional analysis are employed in this study, data are required on farm resources, organization and production. Major reliance has to be placed on field survey because this is a necessary source

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[1]Johnson, Glenn L., "The State of Agricultural Supply Analysis," Journal of Farm Economics, May 1960.

[2]Px_{iA} stands for acquisition price of X_i and Px_{iS} salvage value of X_i.

of enough current data for both fitting production functions and constructing the representative farms of the specified universe of farms with the required accuracy.

The information related to the farm organization, resources and production were obtained by conducting the field survey in Clinton and Ionia counties (see below). Technical production and coefficients and enterprise budgeting information for a specific area are usually difficult to obtain by survey, therefore, the main sources of such data used in this study are published articles and bulletins and unpublished research reports in Michigan. In case the required data were not available, guesstimates were obtained from well-informed persons working in that specific field. The data used in the linear programming and functional analyses were summarized in Appendix A.

The Sample

The data used in this study were obtained from sixty-one cash grain farms[3] in Clinton and Ionia counties for the operating year 1972.

Sampling procedures were divided into two steps. (a) A random sample of twenty predominantly Miami/Conover areas (two mile square area containing four square miles), 10 areas for each county, was drawn from the 85 such areas

[3]Cash grain farms defined in this study were the farms deriving 50 percent or more of their farm income from the sale of corn, soybean, field beans, wheat and small grains.

of Miami/Conover soil in the two counties. (b) Sixty-one cash grain farmers, 30 in Clinton county and 31 in Ionia county in the 20 areas were interviewed. Detailed farm management and crop production information was secured. The records on livestock production were not obtained. Livestock and all other farmers whose farmsteads fell in selected areas were also interviewed. However, only information related to their farm land use in 1972 was obtained.

The cash grain farms sampled in Clinton and Ionia counties indicated a substantial range in gross income and factor input categories. The lowest gross income was $2,131 and the highest was $189,396. The acreage involved ranged from a low of 22 to a high of 1,800 acres. A considerable range also existed in the amount of labor used--the smallest amount being one month and the largest 32 months. Machinery investments ranged from a low of $3,100 to a high of $93,375, while operating expenses ranged from a low of $438 to a high of $53,170. The wide range in inputs and investments made it possible to estimate the separate influence of various input categories on gross income.

The Survey Schedule and Interviewing

Two kinds of survey schedules[4] were developed. One was "farm management" schedule which was designed to collect

[4]Copies of the schedules used in this research are included in Appendix C.

the information on production, organization and farm resource inventories and applied to cash grain farmers. The other was "land utilization" schedule which was designed to collect the land utilization information in selected areas in 1972 and applied to all farmers in the area.

The data were collected by personal interview with the farm managers. The interview was conducted by the author and two other graduate student assistants in the Department of Agricultural Economics at Michigan State University in the fall of 1973. Each farmer was contacted personally at his farm. During this visit, the purpose and nature of the study was explained and a tentative appointment was made. Though most farmers cooperated, a refusal rate of approximately 6 percent was experienced. Farm sizes for farmers who refused ranged from 120 to 155 acres, which was not significantly different from average of those visited (i.e., 142 acres). Of the 61 farms investigated, 30 farms (49 percent) were full-time farm and 31 (51 percent) were part-time farm.[5]

Processing of Data

After completion of the field survey, the data were first coded, tabulated and punched for IBM card operations. The information concerning production, inventory, expenses and investment was used in performing production function

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[5]The part-time farms defined in this study are those where the operator has 90 or more days of work off the farm.

analysis. The classification of farms was made on the basis of net worth and operator's age information. The resource inventory and financial data were used to determine the initial resource constraints for representative farms.

The derivation of production function and the computation of linear programming were both carried out on the CDC 6500 computer at Michigan State University. CDC Apex I together with the Harsh-Black routine were used for the linear programming computation.

Defining Representative Farm

Since the cost of programming every farm would be prohibitive, it was essential to set up a representative farm in carrying out the linear programming analysis.

In setting up the representative farms, it was essential that the farms in a class should be sufficiently homogeneous with respect to the key variables that affect farm adjustment.

In this study, the different groups of the representative farms consisted of farms and farmers who were sufficiently homogeneous in terms of willingness and ability to make farm adjustments. These were indicated by the following: One variable, age of operator, was used to represent homogeneity with respect to willingness to make adjustments. Generally speaking, it is widely accepted as true that the younger farmer is more willing to make changes because the probability of realizing personal gains in the future is greater. Farm operators were classified in terms of age of operator into two groups, 24 to 55 years and over 55 years.

Another variable, net worth, was used to represent homogeneity in terms of ability to make changes. Net worth is needed to acquire land, machinery, labor and make operating expenditures. A farmer can hardly make the necessary adjustments even under most favorable conditions unless he has considerable net worth to provide credit and/or cash on hand.

In this study, farmers were stratified by age of operator and net worth as a major determinant for setting up representative farms. The age-net worth classification for all qualifying farms is shown in Table 2.1.

Table 2.1. Number of Farms in Each Age-Net Worth Classification

Age of Operator	Net Worth		
	$30,000-80,000	$80,000-150,000	Over $150,000
24 to 55 years	10	17	21
Over 55 years	2	7	4

From the above classification of farms, four representative farms: small, medium, large and medium* farms were developed. The medium* farms refer to the farms with net worth $80,000-150,000 and operator's age over 55 years.

Each representative farm stratum consists of at least seven farms as shown in Table 2.1. The resources of the farmers in these strata were used as the initial resource restrictions for each representative farm.[6]

The levels of the initial resources in each case except machinery were based on farm averages of those making up the net worth-age strata. In the case of machinery, the restrictions were determined on the basis of the kinds and amounts of machienry that majority of farms had in the strata. The initial resources for representative farms are presented in Table A-1 in Appendix A.

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[6]It is assumed that the input-output coefficients are the same for all representative farms, however, the initial resources are different for each farm.

CHAPTER III

THE ANALYTICAL MODEL

Two analytical models are used in this study. One is a linear programming model which is used to analyze the optimum organization of the farm. Another is a production function model which is used to measure the productivities of inputs and investments. In this chapter the two models are explained in order.

Linear Programming Model

Linear programming deals with the problem of optimum allocation of scarce resources among competing activities. In this sense, it is often called "activity analysis." The allocation problem arises whenever one must choose the level of some activities which compete for certain limited resources essential to perform the activities.

Three important components are involved in a linear programming model: (1) objective function, (2) resource constraints and (3) activities or processes. The mathematical model is as follows:[1]

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[1]Dorfman, R., Samuelson, P. A. and Solow, R. M., Linear Programming and Economic Analysis, (New York: McGraw-Hill, 1958).

$$\text{Maximize } Z(X) = C_1X_1 + ,\ldots, + C_nX_n \tag{3.1}$$

Subject to restrictions

$$\begin{aligned} A_{11}X_1 + A_{12}X_2 + ,\ldots, + A_{1n}X_n &\leq B_1 \\ A_{21}X_1 + A_{22}X_2 + ,\ldots, + A_{2n}X_n &\leq B_2 \\ \vdots \qquad\qquad\qquad\qquad & \vdots \\ A_{m1}X_1 + A_{m2}X_2 + ,\ldots, + A_{mn}X_n &\leq B_m \end{aligned} \tag{3.2}$$

$$X_i \geq 0 \quad i = 1,2,\ldots,n \tag{3.3}$$

In matrix form, the model can be formulated as follows:[2]

Maximize $Z = C'X$

Subject to restrictions:

$AX \leq B$

$X \geq 0$

Where:

C = nx1 vector of prices

X = nx1 vector of activity levels

A = mxn matrix of input-output coefficients

B = mx1 vector of resource restrictions

It is required to find n numbers $X_1, X_2,\ldots,X_n$ which make Equation (3.1) as great as possible, where $C_1,\ldots,C_n$ are given constants subject to the restrictions that no X

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[2]Heady, Earl O., and Candler, Wilfred, Linear Programming Methods, (Ames, Iowa: The Iowa State University Press, 1959) p. 416.

shall be negative and that the X's shall satisfy the m inequalities, i.e., Equation (3.2).

In order to have a precise solution, the problem under consideration must meet several assumptions in the model. These assumptions are:[3]

1. Additivity and linearity of the activities.
2. Divisibility of activities and resources.
3. Finiteness of alternative activities and the resource restrictions.
4. Single-value expectations--i.e., resource supplies, input-output coefficients and prices are known with certainty.

It is also required to assume that maximization of Z is the only motivation for entrepreneurs or farmers in order to fit the problem in linear programming scheme.

Very few problems in the real world can precisely fulfill all the assumptions built in the linear programming model. The assumptions of additivity and linearity, divisibility and single-value expectations are of particular concern. However, as a technique of linear programming has been improved combined with the availability of high-speed electronic computers to a solution of the linear programming routine, some of the difficulties in applying the model have been alleviated. A model can more easily be modified in such a way that it can nearly approximate

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[3] *Ibid.*, pp. 17-18.

the conditions of the particular problem under consideration. To add special constraints on resource use in handling the risk and uncertainty problem is one example.

The model used in this study consists of many activities and equations which are usually used in studying the resource allocation problems at the firm level. However, the structure and size of matrix are rather complex and large and need explanation in some detail. This is especially true for the credit and asset acquisition activities, because they involve some aspects peculiar to this model.

In order to explain the model the whole structure of the model which includes activities, constraints and input output coefficients is presented in Table 3.1. Sixty-two equations (i.e., resource restrictions) and 92 variables (i.e., activities or processes) are included in the model. The incorporation of investment/disinvestment theory into a linear programming framework requires the addition of one or more acquisition and salvage activities for each of the resource categories to be incorporated into the model.[4]

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[4]For an application of the theory to a linear programming model see: Johnson, G. L., op. cit.; Smith, V. E. "Perfect vs. Discontinuous Input Markets: A Linear Programming Analysis," Journal of Farm Economics, Vol. 37, August 1955, p. 538.; Edwards, Clark,"Resource Fixity, Credit Availability and Agricultural Organization,"unpublished Ph.D. dissertation, Michigan State University, 1958; and Hildebrand, Peter E.,"Farm Organization and Resource Fixity: Modifications of the Linear Programming Model," unpublished Ph.D. dissertation, Department of Agricultural Economics, Michigan State University, 1959.

Structure of Linear Programming Tableau

The activity set used in the model is denoted by:

$P_1, \ldots, P_m$; $S_1, \ldots, S_w$; $Q_1, \ldots, Q_6$; $N_1^{hl}, \ldots, N_t^{hl}$; N_1^{hm}; $N_1^{sf}, \ldots, N_t^{sf}$, $N_1^{sm}, \ldots, N_t^{sm}$; L_1^{pl}, L_2^{pm}, L_3^{s}, L_4^{ri}, L_5^{ro}, L_6^{wc}, L_7^{pc}; $M_1^{b}, \ldots, M_r^{b}$; $M_1^{s}, \ldots, M_u^{s}$

Where:

$P_1, \ldots, P_m$ are activities associated with m crop rotation producing activities (e.g., wheat-bean, corn-bean-soybean, etc.).

$S_1, \ldots, S_w$ are activities involving selling W crop outputs for cash.

$Q_1, \ldots, Q_6$ are activities associated with credit borrowing and selling. Q_1 to Q_5 represent chattel mortgage, real estate mortgage, land contract, land mortgage and machinery dealer credit, respectively and Q_6 represents a saving account.

$N_1^{hl}, \ldots, N_t^{hl}$ are activities involving hiring seasonal unskilled labor.

N_1^{hm} is an activity associated with hiring managerial labor.

$N_1^{sf}, \ldots, N_t^{sf}$ are activities involved in selling family labor for nonfarm work.

$N_1^{sm}, \ldots, N_t^{sm}$ are activities associated with selling operator labor for nonfarm work.

L_1^{pl}, L_2^{pm}, L_3^{S}, L_4^{ri}, L_5^{ro}, L_6^{wc}, L_7^{pc} represent land purchase by land contract, and mortgage, land selling, land rent-in, land rent-out, woodland clearance and pasture clearance activities, respectively.

$M_1^b, \ldots, M_r^b$ are activities involving purchase of r machinery.

$M_1^s, \ldots, M_u^s$ represent selling u machinery.

The model assumes income maximization as the only objective for farming. Therefore, the Z in the objective function would represent the total returns of owned assets.

The C_j's in the objective function represent either unit cost (negative) or unit net price (positive) depending on the nature of activities. In the case of crop producing activities, the C_j's (negative) are the per unit acreage variable cost (i.e., CE + R = cash expenditures and repairs) for crop production (per unit acreage may be 2 acres or 3 acres depending on a type of crop rotation). The C_j's (negative) in the land clearance activities are the per acre cost of owning land (real estate tax) plus per acre cost of clearance including tiling cost computed by the amortization principle.[5] In the land purchasing activities

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[5]The formula of computation is:

$$C = \frac{P_o(1+r)^t}{t}$$

Where: C = current cost; r = rate of interest; t = usable life and P_o = initial cost.

the C_j's are the amount of real estate tax payment per acre. In the credit (borrowing) activities the C_j's (negative) are the interest charges per dollar of credit. The C_j's in the machinery purchasing activities reflects the cost to the farm of owning the asset. That is, the annual depreciation and taxes that incur by owning machinery.[6] On the other hand, the profit equation coefficients for machinery sales activities are the savings (taxes plus depreciation) to the farm of not owning the asset.

Thus, Z in the objective function represents returns to fixed resources (i.e., gross income less variable costs) from each of the producing activities. In the producing activities the X_i's show the level of the different activities, including production, disinvestment and investment, and other activities to which the resources may be allocated.

All crops produced are first transferred into crop transfer equation so that crops can be sold through selling output activities. This scheme is used because it was desirable to study the effect of changing output prices.

The B_i's represent the quantity of various farm resources available on the farm and/or some other restrictions which limit the use of farm resources. Farm labor is divided into five seasons according to the seasonal pattern of cash crop production. December through March

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[6]There are no taxes on farm machineries in Michigan. Therefore, machinery tax is excluded in the objective function.

Tableau 3.1 Structure of the Input-Output Matrix[1]

Activities / Restrictions (B_i)		Crop Production	Sell Output	Credit (Borrowing)					Saving	Unskilled Labor Hiring	Hiring Managerial Labor
		$P_1,\dots,P_m$	$S_1,\dots,S_w$	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	$N_1^{hl},\dots,N_t^{hl}$	N_1^{hm}
Revenue or cost		$-(CE+R)_j$	C_j^s	$-i_1$	$-i_2$	$-i_3$	$-i_4$	$-i_5$	i_6	$-C_j^{hl}$	$-C_1^{hm}$
Cropland	≥	$a_{i1},\dots,a_{im}$									
Woodland	≥										
Plowable Pasture	≥										
Cash	≥	$(CE+R)_{ij}$		$-(1-i_1)$	$-(1-i_2)$	$-(1-i_3)$	$-(1-i_4)$	$-(1-i_5)$	1	$a_{i1},\dots,a_{it}$	a_{ij}
Seasonal Labor	≥	$a_{i1},\dots,a_{im}$ a_{ij} $a_{i1},\dots,a_{im}$								-1 -1 . . . -1	a_{ij} ⋮ a_{ij}
Annual Labor	≥	$a_{i1},\dots,a_{im}$								-1, . . ., -1	1
Crop Transfer	≥	$a_{i1},\dots,a_{im}$ a_{ij} $a_{i1},\dots,a_{im}$	1 . . . 1								
Managerial Labor	≥	$a_{i1},\dots,a_{im}$									1
Operator's Off-farm Work	≥										
Family Labor's Off-Farm Work	≥										
Chattel Mortgage	≥			1							
Real Estate Mortgage	≥				1						
Land Contract	≥					1					
Land Mortgage Credit	≥						1				
Machinery Dealer Credit	≥							1			
Land Purchase Limit	≥										
Land Rent-in Limit	≥										
Tractor Capacity	≥	$a_{i1},\dots,a_{im}$ a_{ij} $a_{i1},\dots,a_{im}$									
Machinery Capacity Plowing	≥	$a_{i1},\dots,a_{im}$									
Discing	≥	$a_{i1},\dots,a_{im}$									
Cultivating	≥	$a_{i1},\dots,a_{im}$									
Planting	≥	$a_{i1},\dots,a_{im}$									
Harvesting	≥	$a_{i1},\dots,a_{im}$									

Tableau 3.1. Continued

Activities / Restrictions (B_i)		Selling Family Labor $N_1^{sf}, \ldots, N_t^{sf}$	Selling Managerial Labor $N_1^{sm}, \ldots, N_t^{sm}$	Land Purchase L_1^{pl}	L_2^{pm}	Land Sell L_3^{s}	Land Rent-in L_4^{ri}	Land Rent-out L_5^{ro}	L_6^{wc}	Pasture Clearance L_7^{pc}	Purchase Machinery $M_1^{b}, \ldots, M_r^{b}$	Sell Machinery $M_1^{s}, \ldots, M_u^{s}$
Revenue or cost		C_j^{sf}	C_j^{sm}	$-T_1$	$-T_2$	T_3	$-C_4^{ri}$	C_5^{ro}	$-C_6^{c}$	$-C_7^{c}$	$-(D+T)_j$	$(D+T)_j$
Cropland	$\geq$			-1	-1	1	-1	1	-1	-1		
Woodland	$\geq$								1			
Plowable Pasture	$\geq$									1		
Cash	$\geq$	$-a_{i1}-a_{i2}-a_{i3}\cdots$	$-a_{i1}-a_{i2}-a_{i3}\cdots$	P_1	P_2	$-.25P_3$			a_{ij}	a_{ij}	$(P_A)_{ij}$	$-(P_S)_{ij}$
Seasonal Labor	$\geq$	1 1 $\cdot$ $\cdot$ 1	a_{i1} $\cdot$ $\cdot$ $\cdot a_{it}$									
Annual Labor	$\geq$	$1, \ldots, 1$	$a_{i1}, \ldots, a_{it}$									
Crop Transfer	$\geq$											
Managerial Labor	$\geq$		$a_{i1}, \ldots, a_{it}$									
Operator's Off-Farm Work	$\geq$		$1, \ldots, 1$									
Family Labor's Off-Farm Work	$\geq$	$1, \ldots, 1$										
Chattle Mortgage	$\geq$											$(.50P_S)_{ij}$
Real Estate Mortgage	$\geq$					$.50P_3$			$-.5a_{ij}$	$-.5a_{ij}$		
Land Contract	$\geq$			$-.75P_1$								
Land Mortgage Credit	$\geq$				$-.50P_2$							
Machinery Dealer Credit	$\geq$										$-(.75P_A)_{ij}$	
Land Purchase Limit	$\geq$			1	1							
Land Rent-In Limit	$\geq$						1					
Tractor Capacity	$\geq$										$-a_{i1}, \ldots, -a_{ir}$ $-a_{ij}$ $-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$ a_{ij} $a_{i1}, \ldots, a_{iu}$
Machinery Capacity												
Plowing	$\geq$										$-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$
Discing	$\geq$										$-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$
Cultivating	$\geq$										$-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$
Planting	$\geq$										$-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$
Harvesting	$\geq$										$-a_{i1}, \ldots, -a_{ir}$	$a_{i1}, \ldots, a_{iu}$

[1] In tableau negative signs preceeding the coefficient in profit equation indicate costs and positive signs indicate incomes, while negative signs preceeding the production coefficients indicate adding to the resource and no signs refer to consuming resource.

labor is considered as one resource as at this time period, a cash crop farmer does not work much on his farm. Season 2 (April and May) and season 3 (June and July) make up the planting, cultivating and wheat harvesting period. Season 4 (August) is considered as a slack period. Season 5 (September, October and November) is a harvesting and fall planting period.

Tractor services, measured in hours, are broken down into five periods and their availability for field time usage is determined by the following factors: (1) the number of work days in the period; (2) the percentage of days suitable for field work and (3) the maximum number of hours each day that the tractor can be expected to be in the field. The availability of the field time for machinery services is determined by the specific time period in which the machines are needed. The number of acres that can be covered by a machine in a 10-hour day in a specific time period are used as a measurement of machinery services.

By specifying the objective function with constraints, the programming model selects the X_i's at a level that does not exceed the prespecified restrictions. The set of X_i's in the programming result indicates an optimum combination of production activities, investment and disinvestment activities, credit and other activities.

Resource Restrictions

In the model all resources except net worth (land to some extent) were variable and therefore presented no limit to production. Resources could be purchased once it was exhausted and if it was profitable to do so. They could also be sold once their value in use is less than their salvage value. The most limiting resources for all representative farms was the capital resources which were determined by credit available and net worth. The annual cash resource included cash on hand, near cash assets, and crop inventories valued at current prices. Debts against crop inventories were deducted from the annual cash resource.

The initial level of real estate mortgage resource was defined as the funds that farm operators thought they could borrow from public credit institutions taking into account the current value of land and other assets less outstanding debts against such assets. The initial amount of the chattel mortgage resource was estimated at 50 percent of the current value of the machinery inventory minus any outstanding debts against such assets.

Cost of credit varies with the source. Money could be borrowed at 8 percent per annum using real estate mortgage or 9.5 percent per annum using a chattel mortgage whereas dealer credit costs 14 percent per annum. The initial cash on hand could be saved at 6.5 percent per annum. A further explanation of the credit resources will be given in the next section.

The determination of the initial levels of the potential land rentals and land purchases were based on the data collected on the field survey. During the survey, farmers were questioned as to the quantity, location and quality of land available for rent and for purchase in the area of three miles square around the farm. Also, an effort was made to eliminate all double counting. This information was used to determine the prices and quantities of land for purchase and rent for representative farm situations (see Table A-1 in Appendix A).

Activities

The model includes several major activity groups such as crop production, credit, labor, land and machinery activities. The activity groups in the model are explained as follows:

Crop Activities

In the model, twenty-one rotations are provided as cropping alternatives with an additional five selling output activities. Each crop rotation is composed of two or more of the following crops: i.e., corn (C), soybean (S), wheat (W), field beans (B) and oats (O).[7] As the yields, herbicide costs and level of fertilization differs for the same crop with different crop rotations, separate crop

[7] The Letters in the parentheses are used to denote the crop rotation.

budgets were developed taking into account the different crop rotations.[8] The crop budgets used in the model are presented in Table A-2 to Table A-9 of Appendix A.

Levels of crop yields, fertilization, capital, labor input and machinery required for each rotation apply to a unit of rotation, containing one acre of each crop in the rotation. For example, a unit of CCBW rotation (corn-corn-bean-wheat) includes two acres of corn, one acre of field beans and one acre of wheat.

In the tableau the negative sign preceeding the coefficient in the profit equation indicates variable costs and no sign indicates income, while negative signs preceeding the production coefficients indicate adding to the resource and no signs refer to consuming resource. No institutional restrictions were imposed in the model since there would be no government set-aside of land in 1974 for feed grains, soybeans and wheat.

It is worth noting that the income from sales of products does not add to cash to be used in crop production. The reason for this is that crop sales income is received after most of crop expenditure has been spent. However, the inventories of last year's crop are added to cash for crop production.

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[8]The crop rotations and input-output coefficients were developed through consultations with Lynn Robertson of the Soil Science Department and Milton Erdman and S. C. Hildebrand of the Crops Department, Michigan State University.

Credit Activities

In the model, a group of credit activities are included so that additional credit could be obtained against present chattel assets and real estate as well as from dealers for buying machinery or other assets.

The group of credit alternatives includes: chattel mortgages (Q_1), real estate mortgage (Q_2), land contracts (Q_3), obtaining credit on newly acquired land (Q_4), machinery dealer credit (Q_5), and savings account for surplus cash (Q_6).[9]

The chattel mortgage credit costs $0.095 for each dollar borrowed, adds $0.905 to cash, and uses $1 of the credit limit. Real estate credit costs $0.08 per dollar, furnishes $0.92 to cash and uses up $1 of the real estate credit limit.

Purchasing land or new machinery furnishes additional credit for farmers. These credits are available only with the purchase of land or machinery. However, the model would not force the use of credit, unless it was profitable to do so. The land contract credit costs $0.09 per dollar of credit and adds $0.91 cash while using up $1 of credit limit. When land is purchased on real estate mortgage, an additional land mortgage credit activity is allowed to be activated. This activity costs $0.085 per dollar borrowed and furnishes $0.915 to cash while using up $1 of the credit limit.

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[9]The notation in the parentheses are used in Table 3.1.

Machinery credit costs \$0.14 per dollar borrowed and adds \$0.86 to cash while using up \$1 of the dealer credit limit.

In the model the credit acquisition activities handled all interest costs. The cash saving activity (Q_6) provide an opportunity cost of 6.5 percent for the initial cash on hand. This implies that capital used on farm, either for asset purchase or production, have to bring at least 6.5 percent returns or the resources will not be used on the farm.

Labor Activities

A perfectly elastic supply schedule for labor was assumed.[10] Seasonal unskilled labor and managerial labor could be hired without limit in any of the five time periods whenever family labor were insufficient to meet all labor requirements on the farm. On the other hand, two off-farm alternatives were added to provide the opportunity of off-farm work for operator and family labor. Operator and family labor may be hired out at \$5.75 and \$2.55 per hour, respectively.

Restrictions on the quantities of off-farm work for operator and family labor were based on the average hours of off-farm labor obtained in the year covered by the field survey.

Hiring managerial labor activity (N_1^{hm}) costs \$5.80

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[10]Farmers interviewed indicated that they could hire enough labor in the five time periods.

per man hour, uses $5.80 cash, adds one hour to annual labor which was distributed by periods, and contributes one hour to the managerial labor restriction. The wage rate of $5.80 per hour was based on a 40-hour week with an annual income of $12,000.

Land Activities

The model provided alternative activities such that capital could be used to purchase land as well as for the clearance of land or renting of land.

Land could be purchased either on a land contract basis (L_1^{pl}) or on a mortgage basis (L_2^{pm}). The former requires a 25 percent down payment furnishing 75 percent land contract credit while the latter needs 50 percent down payment providing 50 percent mortgage credit. The prices and quantities of land available for rent and for purchase were determined by the data collected on field survey. The estimated quantity of land for rent was 134, 184, 131, respectively for small, medium and large farms and the potential quantities for purchase were 117, 82 and 54 correspondingly for small, medium and large farms. The rental rate was estimated at $30 per acre, while the purchase price was estimated at $500 per cropland acre.[11]

[11] In analyzing the effect of land availability on the optimum organization, it was further assumed that a substantial quantity of high priced land could be purchased and/or rented at a higher price in order to approximate the empirical assumption that the supply of land is not perfectly elastic. (This is not shown in the Tableau.)This

The model also provided alternatives for selling land at price of \$500 per acre and renting out land at an annual rental rate of \$30 per acre. Two land clearance activities were incorporated in the model. One is clearance activities for woodland requiring \$500 clearance cost per acre of woodland and the other is for plowable pasture land requiring \$395 clearance cost per acre. The C_j's in these two activities were the annual clearance cost computed by the amortization principle, i.e.,

$$C = \frac{P_o(1+r)^t}{t}$$

Where C is the current cost, P_o the initial land clearance cost, r, the interest rate and t is the usable life.

By permitting land and associated durable resources to vary in the model, one could observe the effects of varying land area on the optimal organization of a farm.

Machinery Activities

The linear programming model provided for acquisition and disposal of machinery and equipment. Economic theory states that a profit-maximizing entrepreneur will employ a variable productive service until the point is reached at which the marginal value product equals its marginal factor cost.[12] Likewise, a profit-maximizing entrepreneur

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was defined as land B in the model. The costs to obtain control of an acre of land B were \$600 and \$35, respectively for purchasing and renting.

[12] Ferguson, C. E., Microeconomic Theory, (Homewood, Ill., Richard D. Irwin, Inc., 1969) p. 404.

would not acquire an additional unit of machinery unless the annual marginal value product of the machinery exceeds its annual marginal factor cost. The annual marginal factor cost of an asset includes depreciation, taxes, interest and repair.

Consequently, the annual marginal value product of the machinery purchased has to be at least equal to the sum of depreciation, interest, repair and taxes of the asset. Since repairs are basically a variable cost in nature, they are charged as variable cost in the crop producing activities.[13] Furthermore, as stated previously the credit acquisition activities handled all interest costs. Therefore, the profit coefficients in the machinery acquisition activity represented only the depreciation and taxes (D+T) which is the cost of the annual flow of services from the asset. By the same token, the profit coefficients for machinery sales activities were the savings to the farm of not owning the machinery. It is assumed that a 25 percent of down payment was required when machinery was purchased providing 75 percent of machinery dealer credits.

Discrete Investments

There is a problem in interpreting the results of linear programming due to the divisibility assumption made

[13]This study does not consider the user cost problem which deals with the economics of deciding on the optimum rate at which to generate service from durable assets.

in the model. In linear programming, resources and products are assumed to be infinitely divisible. Therefore, the results of linear programming will include the fractional unit of activities and resources. There are several ways to solve this problem. Integer programming which is being developed at Michigan State University will partially overcome this problem.[14]

The other alternative is to fix the discrete investment to the nearest unit higher than and lower than the fractional unit present in the optimal solution with all assets assumed to be infinitely divisible. The program is then re-run twice, once using higher value restrictions and once using the lower value restriction, and select the plan giving a higher profit.[15] The selected organization is less profitable than the previous organization since purchasing whole unit of assets impose a greater capital restriction on the farm. This procedure has two pitfalls. First, this integer solution may be infeasible. Secondly, this solution may be too far from optimality, even if it is feasible. In order to reach the optimal integer solution, it may require a much more drastic realignment of the decision variable values than merely rounding off.

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[14]CDC Apex II routine which is designed to solve the integer programming problem is being developed on the CDC 6500 computer at Michigan State University.

[15]Hildebrand, P.E., op. cit., Chapter II.

Another alternative is to deal with discrete assets as a flow rather than a stock. In this case, it can be considered as a continuous input. For example, a tractor can provide many hours of service which can be considered as a continuous input. Also, the fractional units of machines can be interpreted as purchasing machines which embody different amounts of services by acquiring those of different sizes or ages, or simply viewed as custom service hired.

In this study, no effort was made to solve the problem of the fractional unit of activities and resources in the optimum plan for two reasons. First, the approach adopted by Hildebrand[16] could not handle the problem adequately. Secondly, Apex I routine used in this study gives the range of a machine over which the optimal solution remains stable. By using this information a program can be rounded to include activities produced to the nearest whole unit without causing serious decision making errors. In case that the rounding is beyond the range, we allow the fractional units of inputs and could be viewed as custom service hired.

Production Function Model

One of the approaches to the problem of optimum resource allocation is to estimate a production function from which the elasticity coefficients of production and the marginal value products of factors can be estimated.

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[16] Ibid., Chapter II.

The estimated marginal value products of each input can then be compared with the estimated marginal factor cost of respective variable inputs. If the comparisons show that the ratio existing between marginal factor cost and marginal value product is substantially different for each variable factor used by the farm, a proposed reorganization for applying different levels of inputs until the ratios are equal for each variable input would increase net farm income.

All inputs combined in optimum proportions can be increased until the ratio between marginal factor cost and marginal value product for each variable input becomes equal to one. Under this condition, the high profit point is reached and the optimum level of resource use is determined.

There are several algebraic forms which can be used to fit the production function. The ones most commonly used are: Cobb-Douglas, Spillman, quadratic, power and square root functions. Many factors should be considered in order to select the appropriate functional forms. The basis for selection of alternative formulas include ease of fitting and manipulating, statistical goodness of fit, empirical evidence and economic theory. In this study, the Cobb-Douglas type function[17] will be chosen because of

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[17]Earl O. Heady and John L. Dillon, Agricultural Production Functions (Ames, Iowa, Iowa State University Press, 1961) pp. 73ff.

its goodness of fit to the data, efficient use of degrees of freedom and computational feasibility. The equation is of the form

$$Y = AX_1^{b_1} X_2^{b_2} \cdot \cdot \cdot \cdot X_n^{b_n} \qquad (3.4)$$

Where Y represents output, the dependent variable, and $X_1, \ldots, X_n$ represents the independent variables that determine output. The exponents b_i $(i = 1, \ldots, n)$ are the elasticities of the independent inputs X_i $(i = 1, \ldots, n)$ with respect to the dependent variables (Y). The values of these exponents indicate percentage change in output associated with a one percent change in the respective input factors while keeping all other inputs constant. If they are not forced to one, $\sum_{i=1}^{n} b_i < 1$ indicates decreasing $\sum_{i=1}^{n} b_i > 1$ indicates increasing returns to scale.

The model can be expressed in logarithmic form as follows:

$$\text{Log } Y = \log A + b_1 \log X_1 + b_2 \log X_2 + , \ldots , + b_m \log X_n \qquad (3.5).$$

The function is linear and is easily fitted to empirical data by the least squares regression technique. The regression coefficients (b_i) are in natural numbers and the only transformation required where the function is to be written in exponential form is the conversion of the constant "A" back to the natural numbers. The power function permits the phenomenon of decreasing marginal returns to appear without using up many degrees of freedom.

The marginal value productivities for each factor input can be estimated by using the equation $MVPx_i = \frac{b_i \hat{Y}}{X_i}$ where $\hat{Y}$ is the estimated gross income of the factor inputs, and X_i is the amount of the factor used in the prediction equation.

The Variables

One of the main problems encountered in the application of a Cobb-Douglas function to the analysis of farm data has been that of classification of inputs into homogeneous categories. The ideal situation in input classification is to have the inputs within each category combined in the proportions dictated by the scale line. Since this ideal situation is difficult to reach, Johnson[18] developed a set of rules which insure that it is at least approximated the ideal situation.

1. That the inputs within a category be as nearly perfect substitutes or perfect complements as possible,
2. That categories made up of substitutes (a) be measured according to the least common denominator (often physical) causing them to be good substitutes and (b) be priced on the basis of the dollar value of the least common denominator unit,

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[18]Johnson, Glenn L., "Classification and Accounting Problems in Fitting Production Functions to Farm Record and Survey Data," Resource Productivity, Returns to Scale, and Farm Size, The Iowa State College Press, 1956, Chapter 9.

3. That categories made up of complements (a) be measured in terms of units made up of the inputs combined in the proper proportions (which are relatively unaffected by price relationships) and (b) be priced on an index basis with constant weights assigned to each complementary inputs,
4. That the categories of inputs be neither perfect complements nor substitutes relative to each other,
5. That investments and expenses be kept in separate categories, (The reason for this suggestion is that returns expected from these two types of inputs are different. The expected returns of cash expenses are at least one dollar for the last dollar spent. However, investment categories are expected to return enough to cover maintenance, depreciation, interest and taxes for a given year and are usually less than one dollar per dollar of investment.)
6. That maintenance expenditures and depreciation be eliminated from the expense categories because of the difficulty encountered in preventing duplication. This means that the earning of the investment categories must be large enough to cover maintenance and/or depreciation.

According to the rules developed by Johnson, this study uses total value product (Y) including the sum of all cash sales, home consumption and inventory changes, measured by gross income as the dependent variable. Such sources of income as grant payment for diverted acreage, the rental value of the farm home and investments in nonagricultural sector is not included. Classifications of the independent (causal) variables are: (X_1), land, measured in tillable acres; (X_2), labor, in months; (X_3), operating expenses, in dollars (interest and taxes are considered as nonproductive since no return is expected to accrue from these items); (X_4), machinery investment, in dollars; (X_5), buildings, in dollars.

A Comparison of Cobb-Douglas and Linear Programming Analyses

In general, the problems of resource allocation and the issues associated with supply responses and adjustments in agriculture can be analyzed using several different techniques. Among techniques commonly used are: functional analysis, simulation, budgeting, linear programming and aggregate time series. Cobb-Douglas function analysis and linear programming were employed in the present study. This section compares these two techniques.

Cobb-Douglas Analysis

As a power function, the Cobb-Douglas function has some unique mathematical characteristics; some are detrimental, others useful. The following are some shortcoming inherent in the function: (1) it is monotonously increasing and never reaches a maximum, (2) it cannot simultaneously handle more than one stage of production as it has constant elasticity coefficients for inputs.

On the other hand, the power function has several advantages. The more important advantages are as follows: (1) it is linear in logarithmic form and easily fitted to empirical data, (2) it immediately gives elasticities of production with respect to factors of production, (3) it yields diminishing marginal returns estimates for each productive factor separately without using up too many degree of freedom, and (4) if the errors in production data are small and normally distributed, a logarithmic transformation of the variables preserves normality to a substantial degree.[19]

In addition to the limitations and advantages listed above, the following characteristics should be noted.

1. The Cobb-Douglas function can be used both in estimating parameters of production functions and in finding optima.

In practice, parameters of production function can be obtained by fitting the production function directly to the data. The derivatives with respect to inputs obtained from the Cobb-Douglas function are estimates of the marginal value product of each factor and have the advantage of being computable for any level of the X_i and Y within the range

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[19]Tinter, Gerhard, "A Note on the Derivation of Production Functions From Farm Records," Econometrica, XII, No. 1, January, 1944, p. 26.

of the data from which the function was derived. Furthermore, the estimated marginal value product of each input can be used with the marginal factor cost of the respective variable inputs to determine optimal resource allocations. Therefore, the Cobb-Douglas function can be used: (1) to estimate parameters and (2) to locate optima, while linear programming can only be used to locate optima.

2. The Cobb-Douglas function can deal with the problems of enterprise combinations and resource allocation. However, it is difficult to use on multiple enterprise farms. In other words, the function is more difficult to use in analyzing farms having diversified enterprises. This is due to the fact that the effect on gross income obtained from one enterprise of an input category may be substantially different than in another and the proportion of the two may vary greatly from farm to farm. However, this problem can be avoided by choosing a group of farms producing similar products, or with adequate enterprise accounting for both outputs and inputs.[20]

3. In practice, the Cobb-Douglas function is best used when it involves imperfect complements and substitutes among broad input categories with high complementarity and

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[20]Beringer analyzed individual enterprises on multiple enterprise farms with adequate accounting of outputs and inputs. (See: Christoph Beringer, "A Method of Estimating Marginal Value Productivities of Input and Investment Categories on Multiple Enterprise Farms," Unpublished Ph.D. dissertation, Michigan State University, 1955.)

only substitutability among inputs left within input categories.

A problem encountered in the application of Cobb-Douglas functions in the analysis of farm data has been that of classifying inputs into categories. Johnson[21] through analytical reasoning developed rules which proved useful in this study. The rule is to group good complements together and good substitutes together, measuring the complements in terms of "sets" and the substitutes in terms of the common denominator which makes them good substitutes. The resultant sets of complements and sets of substitutes can sometimes be grouped into larger categories on the basis of the same rules. Consequently, input categories defined should be neither good substitutes nor good complements for each other. This avoids much of the specification bias with which Griliches was later concerned.[22]

4. The Cobb-Douglas function can be used to investigate increasing or decreasing returns to scale. When the sum of the elasticities is larger than one ($\Sigma b_i > 1$), increasing returns to scale are indicated; when the same sum is less than one ($\Sigma b_i < 1$), decreasing returns to scale are evidenced; and when the sum is equal to one ($\Sigma b_i = 1$), constant returns to scale are indicated.

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[21] Johnson, Glenn L., _op_. _cit_., Chapter 9.

[22] Griliches, Zvi. "Specification Bias in Estimates of Production Function," _Journal of Farm Economics_. Vol. 39, 1957, pp. 8-20.

5. Some effects of change in the amount of supporting inputs and investments on the estimates of the marginal value products of an input category can be measured. The function is capable of measuring some of the effects of interaction of different levels of inputs and investments on their respective value productivities. Although linear programming has such capability if enough activities are used in the model, the cost of including enough activities is often prohibitive in terms of additional complexity and computing.

6. The Cobb-Douglas function permits estimates of the marginal value productivity of one input category to be made without arbitrarily assuming the earning power of other input categories as in accounting work.

7. The Cobb-Douglas function can indicate which resources are economically fixed and which are candidates for investment or disinvestment by comparing the estimated marginal value products of specific resources to both salvage value and acquisition price of corresponding inputs and investments. However, stock-flow conversion problems arise because of the unsolved user cost problem in economic theory.

8. Statistics can be used to provide measures of significance of the parameter estimates for a Cobb-Douglas function; however, some of the tests of the significance of the difference between MVP and MFC are of questionable

validity due to the difficulties involved in estimating the variance of marginal value productivity.[23]

Linear Programming Analysis

As an optimizing model, linear programming can be applied to the great variety of situations including farm planning, minimum-cost feed formulation and transportation planning. The main advantage of this technique is that it provides computational simplifications not present in analysis of curvilinear production functions due to the smooth, continuous and frequently nonlinear nature of such production functions which make it difficult to work with them mathematically. Linear programming can deal with certain aspects of highly complex enterprise interrelationships by using different activities within and among enterprises. Activities can be set up so that the marginal value product of inputs are bounded by acquisition price and salvage values. In these cases, capital acquisition and disposal activities and the credit activity become very important.[24] However, care has to be taken not to confuse the linear programming MVPs with the partial derivatives

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[23] For a discussion of these see: Carter, H. O. and Harley, H. O., "A Variance Formula for Marginal Productivity Estimates Using the Cobb-Douglas Function," Econometrica, 26 pp. 306-313.

[24] In this study the linear programming model dealing with the endogenous determination of fixed resources is applied.

from a continuous production function because the former are not synonymous with the latter, as will be made clear in Chapter IV.

Linear programming has several unique characteristics.

1. In linear programming, parameters can be easily changed or adjusted with information beyond time series and cross-sectional data. In Cobb-Douglas analysis similar adjustments can be made but with somewhat greater difficulty.[25] In addition, a linear programming model can be modified by adding additional activities so that it can nearly approximate continuous production relationships reflecting imperfect complementarity and substitutability; however, the cost involved in such modification may prove to be prohibitive. Programming is more efficient in locating optimum enterprise combinations.

2. The linear programming model concentrates on perfect complementarity among input categories and either covers up imperfect complementarity and perfect substitutability among inputs within each category or handles them with additional activities.

In general, in linear programming the restrictive resources should be classified according to the following rule: Resources which are perfect or near perfect substitutes should be grouped together leaving as much complementarity

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[25] In this study, the reorganization of farms was based on the adjusted regression coefficients as discussed in Chapter V.

between resource categories. If imperfect complementarity among inputs creates difficulties, it can be handled by introducing more activities while separately handling the complements.

These rules were developed to handle the often contrary to fact linear programming assumption of complementary relationships among inputs.

3. Linear programming can be used to analyze problems of farm adjustment and to estimate supply functions. One of the important advantages of programming is that it permits one to examine the consequences of alternatives within short time period. The question, what would happen if. . .? can be posed repeatedly and answered quickly.[26] Thus the analysis of farm adjustment problem and the estimation of supply functions can be conducted in an environment where no time series of data exist. However, syntheses of macro supply response estimates from micro data using linear programming has not worked well due to inadequate modeling of investment and disinvestment decisions which when modeled destroy weights needed to aggregate micro-economic results into macro-economic relationships. It is difficult to build realistic group restrictions into a linear programming model of the individual firm without unrealistically limiting the firm's adjustment potential. Programming models

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[26] Beneke, R. R. and Winterboer, R., Linear Programming Applications to Agriculture (Ames, Iowa: The Iowa State University Press, 1973) p. 4.

do permit assumptions concerning structural changes to be built into the system.[27] Moreover, they are able to anticipate such changes using recursive programming and/or dynamic programming.

4. One advantage of linear programming is that the sensitivity of the optimal organization to changes in the relative prices, costs and resource levels can be studied. Linear programming can easily answer important questions such as: What is the ranges of prices, resource levels or costs over which a recommended plan remains stable? By definition, sensitivity analysis is a method of examining the changes in the optimal organization due to changes in prices, costs and resource levels of the activities appeared in the optimum solution. The importance of sensitivity analysis is found in examining how much prices, costs or resource levels must change before the optimum solution changes.

5. One of the important values in linear programming is that the shadow prices[28] of excluded activities can be estimated. The shadow prices of the excluded activities indicate the income penalties of forcing an extra unit of an activity into a solution. Therefore, the shadow prices

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[27] Colyer, Dale and Irwin, George D., Beef, Pork and Feed Grains in the Cornbelt: Supply Response and Resource Adjustments, Missouri Agricultural Experiment Station, Research Bulletin 921, p. 35, August 1967.

[28] More detailed explanation about shadow price will be presented in Chapter IV.

of the excluded activities indicate the competitive positions of these activities in the optimal solution. This information has great value in making enterprise combination decisions because it not only indicates what activities are not profitable but how much personal preference might cost if he forces an excluded activity into a plan.

6. Linear programming model handles more resource categories but fewer activities than functional analysis. The cost of extra activities is often prohibitive in additional complexity and computing. Moreover, *a priori* information about productivity coefficients is required before the actual processes involved in the linear programming is undertaken. Therefore, the resultant productivity estimates are dependent on coefficients of productivity obtained independently of linear programming. As such, the evaluation of the appropriateness of estimates of productivity has to be external to the actual programming procedures. In contrast, productivity coefficients for functional analysis are obtained by fitting the production function directly to the data, this raises questions about data adequacy not ordinarily raised explicitly in linear programming analysis.

7. To use statistics to provide measures of significance of the results or to examine elements of risk in the farmer's environment is difficult, if not impossible

with linear programming. If statements about the statistical significance of the programmed results could be offered, the value of optimum solutions to practical farm problems would be largely enhanced.

In constrast, the Cobb-Doublas function being linear in logarithmic form can use statistics to offer limited measures of significance of results.[29]

8. Linear programming concentrates on the opportunity cost principle and can handle investment and disinvestment problems when acquisition and salvage activities are incorporated in the model. Linear programming addresses itself primarily to allocating fixed resources among alternative uses. Since a resource is fixed when its marginal value product is bounded by the acquisition costs and salvage values of the resource, the use of the opportunity cost principle is essential to insure adequate allocation of the use of the services generated by the fixed resources.

By incorporating one or more acquisition and salvage activities into the model for each resource category, the levels of investment and disinvestment can be determined in the optimal solutions.[30] However, the power of linear

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[29]For a discussion of these see: Carter, H. O. and Harley, H. O., op. cit., pp. 306-313.

[30]In this case the resources are allocated according to opportunity costs, salvage values, and acquisition cost, and the model is capable of determining endogenously which resources are fixed and variable.

The inadequacy of the usual neoclassical presentation stems either from an assumption that acquisition costs are programming to deal with investment and disinvestment problems and, hence, farm growth and deterioration is limited by the difficulties encountered in solving the user cost problem.[31]

9. There is a difficulty in understanding the meaning of the so-called marginal value products obtained in linear programs. The difficulty comes essentially from the assumption of perfect complementarity among inputs used in an activity within a linear programming model. Under this assumption, it is obvious that the partial derivative of production function with respect to an input does not exist. Thus, the pseudo linear programming MVPs (MVP_{LP}'s) arise only when other resources are available for use with the resource whose marginal value productivity is being estimated.

As such, the MVP_{LP} of an additional unit of the limiting resource is generated by combining it with other nonrestricting resources. Its value can be very "erratic" depending on how many other resources are unrestricted and in what amounts. The distinction between the two will be examined in more detail in the next chapter.

In order to find a solution by applying linear programming, the problem under consideration has to meet several

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equal to salvage values or from a hidden unrecognized assumption that acquisition costs can exceed salvage values. (See Johnson, Glenn L. and Quance, Leroy, op. cit., p. 34.)

[31] User cost problem could probably destroy the independence of activities and thus reduce its power in handling the investment and disinvestment problem.

linear programming assumptions. Very few problems in the real world can precisely fulfill all the assumptions built into a linear program. The assumptions of divisibility, additivity and linearity and single-value expectations are of particular concern. However, as techniques of linear programming such as integer programming, nonlinear programming, recursive programming and dynamic programming have been improved combined with the availability of high-speed electronic computers to handle linear programming routines some of the difficulties in applying it have been alleviated.

CHAPTER IV

OPTIMUM ORGANIZATIONS FOR THE REPRESENTATIVE FARMS

This chapter presents the programming results of representative farms under (1) fixed land resources, (2) variable land resources and (3) different price combinations. In the first place, the optimal solutions will be given for Model I with cropland fixed at 1972 levels. Secondly, the optimal organizations will be presented for Model II which permits variation in land resources and associated durable assets. In Model II, the farm size is allowed to change through the renting and/or buying land activities. Lastly, the resulting solutions are given for Model II under a number of different price combinations.

The optimal farm plans for the representative farms given in this chapter are based on 1973 product and input prices. The product prices per bushel were: \$2.25 for corn; \$5.50 for soybeans; \$4.25 for wheat; \$1.25 for oats; and \$15.00 per cwt. for dry beans. The initial farm resources used in the program are based on field survey data in 1972 as presented in Table A-1 of Appendix A.[1] Budgets for

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[1]The initial resources used in this model do affect the programmed solution, because the initial resources would be kept in use so long as their shadow price (i.e., value in use) is larger than their salvage value. In other words, their value in use, combining with additional new assets

individual crop which are used in developing the budgets for each crop rotation are presented in Tables A-2 to A-9 of Appendix A.

Optimum Organizations with Fixed Land Resources (Model I)

As previously noted, farm size is not allowed to change in Model I. Managerial labor, machinery and land are assumed to be fixed at the 1972 levels. No alternatives are provided for selling durable assets or selling family labor off the farm but the model permits hiring of unskilled labor to replenish the farm labor when the family labor is used up. The model also includes credit borrowing and cash saving activities.

Table 4.1 presents the optimum organizations (including optimum land use) and the shadow prices[2] of specific resources for the representative farms.

In all farm situations, the four optimum plans call for the same crop rotation which gives the maximum production of wheat and field beans. All the WB rotation in the optimal organizations are operated up to the acreage

or other initial assets, must have shadow price larger than their salvage value. Otherwise, the initial assets would be disinvested and an entirely new type of business brought in if such alternatives are permitted in the model.

[2]Shadow price of limiting resource indicates the amount by which the income would be increased by increasing a unit of resources. Only resources which are scarce have positive shadow prices. More explanation about shadow price will be given in the subsequent section.

Table 4.1. Optimum Organizations and Shadow Prices for Selected Resources for Representative Farms Under Fixed Land Resources (Model I)

Representative Farm	Rotation Acres		Saving Account ($)	Real Estate Mortgage ($)	Shadow Prices			Net[1] Return ($)
					Cropland ($/acre)	Cash ($)	Labor ($/hour)	
Small	W B	93	1,428	---	141	.065	0	13,410
Medium	W B	156	---	395	141	.087	0	22,306
Large	W B	438	307	---	141	.065	0	62,737
Medium*	W B	211	2,827	---	141	.065	0	30,397

[1] The net return is the farm income above the variable cost. It represents return to owned land, capital, labor and machinery.

restrictions. The level of the rotation varies with the different farms because of variations mainly in land resources. The level of net return varies directly with farm size, i.e., net return increases as farm size increases. Labor and capital are not limiting factors as reflected by a zero shadow price for labor and low shadow price for cash. No seasonal labor is required. The provision of saving account alternative in the model furnishes an off-farm opportunity cost or salvage value of at least 6.5 percent for the initial cash on hand. This salvage value is reflected by the shadow price of cash in small, large and medium* representative farms.

The results show that cropland is in short supply as revealed by the shadow price of $141 per acre which is much higher than its marginal factor cost. The high shadow price of cropland indicates that expansion of farm size would be profitable under the assumed yields and prices. It would appear from this model that the provision of supply of land is a crucial factor in increasing the scale of operation and the level of farm income.

An increase in the use of land would tend to reduce its marginal value productivity at the margin but at the same time would increase the marginal earning of labor and capital. Consequently, higher farm income would be generated due to a better farm resource combination involving more land relative to labor and capital. Accordingly the Model

II is designed to examine the potential contribution of varying the levels of land resources on the level of farm income, scale of farm operation and optimum crop rotation.

Optimum Organizations with Variable Land Resources (Model II)

Model II deals with a situation which permits variation in land resources. The model allows a farm to expand or to contract through buying or selling land and associated resources. Model II differs from Model I mainly in that labor, land and machinery are permitted to vary. Acquisition and salvage activities of labor (including managerial labor), land and machinery are added to Model I. In order to model investment and disinvestment in a linear programming framework, the addition of these activities becomes essential. The inclusion of such transaction alternatives, the optimum level of resources can be determined endogenously within the model instead of arbitrarily assuming them fixed. The structure of Model II is presented in Table 3.1.

The initial levels of resources in Model II were the same as those of Model I. The levels of the potential land rentals and land purchases for each farm were determined on the basis of the data collected in the field survey. The estimated quantities of land for rent and land for purchases for each representative farm are shown in Table 4.2.

The annual rental rate was estimated at $30 per acre while the land price was estimated at $500 per acre. These prices are based on what farmers thought they would have to pay for the land that was available for rental or purchases at the time of interview.

Table 4.2. The Levels of Potential Land Rentals and Purchases for Each Representative Farm

Representative Farm	Land (Acres)	
	Renting Limit	Buying Limit
Small	134	117
Medium	184	82
Large	131	54
Medium*	213	114

By providing the opportunity to rent and/or purchase additional land and associated main durable resources, one can observe the effect of additional land supplies on optimal farm plans. The prices of outputs and inputs used in the Model II are the same as those used in Model I.

The programming results indicating the optimum land use and the credit acquired for each representative farm are presented in Table 4.3.

The results show that W B rotation dominates all other crop rotations covered in the model in all farm situations. All the crop rotations appeared in the optimal plans are operated up to the acreage restrictions. The levels of the W B rotation increased above the Model I levels for all farm situations. Consequently, the levels of credit used and net returns increase in all farm situations. Farmers obtain all

Table 4.3. Optimum Organizations and Credit Acquired for Each Representative Farm (Model II)

Representative Farm	Rotation Acres		Credit Acquired ($)				Net Return ($)
			Total	Chattel Mortgage	Real Estate Mortgage	Others[1]	
Small	W B	344	63,678	4,418	18,600	40,660	44,725
Medium	W B	422	49,376	---	31,176	18,200	54,559
Large	W B	496					
	CCCCS	127	34,380	---	34,380	---	83,783
Medium*	W B	422					
	C B	116	75,306	5,270	25,714	44,322	62,057

[1]Other credits include land contract credit, machinery dealer credit and land mortgage credit beyond that owned initially.

the land available for purchase and rent, which allows the expansion of their crop activity levels.

It is worth noting that more crop rotations enter the optimal solutions as more land is obtained. For example, on the large farm, 127 acres of CCCCS rotation enters the optimal solution together with the expansion of W B rotation from 438 acres to 496 acres as more land is obtained. The levels of the activities vary with different farms due to the variations primarily in land resources. As compared with Model I the provision of land rental and purchase opportunity, not only resulted in increased net returns but also changed the optimum combination of crop rotations.

The results show that additional resources have to be obtained or sold in order to achieve optimum farm organizations. Table 4.4 reveals the quantities of specific resources obtained or sold in order to attain the optimum plan for each representative farm. As shown in the table, some additional unskilled labor is hired in all farm situations. There is no managerial labor requirements for the small and medium* farms but approximately 100 and 130 hours of managerial labor is required for the medium and large farms, respectively.

All farms have some members with off-farm work, which agrees with what cash grain farmers were doing in the south central area in 1972. Except for small farms, the family had off-farm work up to the limit of the off-farm work restriction. All farms rent and purchase all the available land

Table 4.4. Investments and Disinvestments Required to Attain Optimum Farm Organization with the Range (Model II)

Resources	Unit	Representative Farm			
		Small	Medium	Large	Medium*
Managerial labor hired	hours	---	103	130	---
Unskilled labor hired	man hr	380	647	366	1,125
Managerial labor sold	hour	1,052	904	587	389
Family labor sold	hour	268	565	411	365
Land rented	acre	134	184	131	213
Land purchased	acre	117	82	54	114
Woodland cleared	acre	---	---	---	---
Plowable pasture land cleared	acre	---	---	---	---
Machinery purchased					
4-bottom plow	No.	---	---	1.72 (1.72-1.72)	.75 (0-.75)
Disc 2 (16')	No.	.03 (.03-2.01)[1]	.21 (.21-2.06)	1.70 (0-3.32)	.74 (0-3.62)
Grain drill (16'-17")	No.	.79 (.31-.79)	.97 (.58-.97)	.26 (.10-.26)	.84 (.58-1.54)
Combine (10', 2 row)	No.	---	---	.10 (0-.12)	---
Machinery sold					
Tractor (53 H.P.)	No.	.55 (0-.55)	.45 (0-.45)	---	.30 (0-.36)
4-bottom plow	No.	.21 (0-.21)	.03 (0-.03)	---	---
Cultivator (4 row)	No.	.06 (.06-1.97)	.08 (.08-1.98)	.20 (.20-1.92)	.04 (0-.33)
Corn picker (2 row)	No.	1.00 (0-1.75)	1.00 (1.00-1.61)	---	.35 (.08-1.70)
Combine (2 row) Pull type	No.	.18 (0-.18)	---	---	---
Spring tooth (12')	No.	.27 (.27-2.07)	.34 (.34-1.88)	---	.49 (0-1.30)
Tractor 2 (70 H.P.)	No.	---	---	.10 (0-.10)	---
Planter (6 row)	No.	---	---	.40 (.40-.50)	---
Spring tooth (16')	No.	---	---	.71 (.71-1.15)	---

[1]Data in parentheses show the range over which the optimum solution remains unchanged.

and increase crop acreages. Neither the woodland nor the plowable pasture land was cleared in the optimal solutions. This indicates that it is not economical to convert woodland and/or pasture land into cropland at the cost of $500 per acre and $395 per acre, respectively under assumed yields and product conditions. However, some pasture land would be cleared under more restricting land resource and/or higher product price condition. This situation will be shown in the next section.

Purchase of some equipment and sales of some machinery are necessary to achieve the optimal farm plans. This is shown in the lower part of the table. The data in parentheses show the range over which the optimal solutions remain stable. It should be noted that the kinds and amounts of machinery bought or sold depend on the kinds and levels of crops that enter the optimal solution. For example, corn does not enter the optimal organization on the small and medium farms, and thus corn pickers are sold out on these farms. On the other hand, corn pickers are retained on the large and medium farms due to the inclusion of corn enterprise in the optimal solution. Original and optimum inventories of machinery for each representative farm are presented in Appendix B.

One of the important values in linear programming is that the shadow prices of scarce resources and excluded activities[3] can be observed. Shadow prices are sometimes

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[3]Excluded activities are the activities that do not enter the optimal solution and are sometimes called "non-basis activities."

called the marginal value products or the marginal costs depending on whether they are referring to the slack (or disposal) activities or the real activities. In general, the shadow prices of the limiting resources indicate the marginal contribution to income of the last unit of resource. It reveals the pressure to expand or contract the use of particular resources. In this sense, it would appear analogous to the marginal value product derived from a continuous function.

However, care has to be taken not to confuse the linear programming MVP (MVP_{LP}) with the MVP from a continuous function (MVP_{cf}) because the former is not synonymous with the latter. By definition, the marginal value product of an input is the addition to total value product attributable to the addition of one unit of the variable input to the production process, other inputs remaining unchanged.[4] It is quite obvious that such a marginal value product of an input does not exist in linear programming due to the assumption of perfect complement relationship among all inputs in the model.

In linear programming, the imputed values to a resource (i.e., shadow price or MVP_{LP}) is estimated at the margin with no other resource restricting.[5] Consequently,

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[4]Ferguson, C. E., op. cit., p. 119.

[5]Lard, C. H. "Profitable Reorganizations of Representative Farms in Lower Michigan and Northeastern Indiana with Special Emphasis on Feed Grain and Livestock." Unpublished Ph.D. dissertation, Department of Agricultural Economics, Michigan State University, 1963, p. 80f.

the MVP_{LP} of a resource is generated by an additional unit of the limiting resource combined with other nonrestricting resources. This type of MVP holds only for an additional unit of resource when all other resources are not restrictive and its value may be very "erratic" for further additional unit of resource. The magnitude of its value depends on which other factors become limiting as an additional unit of the resource is used. The essential nature of corner solutions of linear programming contributes to the "erratic" behavior of the linear programming MVP, i.e., the optimal solutions remain stable for a specific range until one of the other resources becomes restricting, then MVPs of resources change erratically due to change in optimum basis.

The distinction between MVP_{LP} and MVP_{cf} would become more obvious if they were expressed in mathematical form.

Consider the production function:

$$y = f(x_1, \ldots, x_d, x_{d+1}, \ldots, X_g)$$

Where:

y represents total value product;

$x_1, \ldots, x_d$ are variable inputs and hence for all X_i $(i = 1, \ldots, d)$, $0 \geq P_{x_iA} = P_{x_is} \geq 0$ where P_{x_iA} = acquisition price of X_i and P_{x_is} = salvage value of X_i;

$X_{d+1}, \ldots, X_g$ are the inputs which are fixed separately for firm as a whole but allocable among enterprises and hence for all

X_i (i = d+1,. . .,g),

$0 \leq P_{x_i s} < MVP_{x_i} < P_{x_i A} \leq \infty.$

Then

$$MVP_{LP(x_{d+1})y} = \frac{dy}{dX}$$

Where:

$\frac{dy}{dX}$ is a total derivative of y with respect to X, and

$X = (x_1,. . .,x_d, X_{d+1},. . .,x_g)$ while all x_i (i = 1, . . .,g) are combined in fixed proportion, i.e., all x_i (i = 1,. . .,g) are perfect complements as assumed in linear programming under which assumption $\frac{\partial y}{\partial X_{d+1}}$ vanishes.

$MVP_{LP(x_{d+1})y} > 0$ when x_{d+1} is a limiting input and $x_{d+2},. . .,x_g$ are not restricting inputs.

$MVP_{LP(x_{d+1})y} = 0$ when x_{d+1} is a limiting input and simultaneously one of x_i (i = d+2 , . . .,g) is a restricting input or x_{d+1} is a nonrestricting input.

In comparison, marginal value product from a continuous function is as follows:

$$MVP_{cf(x_{d+1})y} = \frac{\partial y}{\partial x_{d+1}}$$

Where:

$\frac{\partial y}{\partial x_{d+1}}$ is a nonvanishing partial derivative of y with respect to x_{d+1}.

It is apparent that:

$$MVP_{LP(x_{d+1})y} \geq MVP_{cf(x_{d+1})} \quad \text{where}$$

$$MVP_{LP(x_{d+1})y} > 0$$

$$MVP_{cf(x_{d+1})y} > 0$$

It should be noted that when x_{d+1} is not a restricting resource, the $MVP_{LP(x_{d+1})y}$ is 0. Only under this condition MVP_{LP} is synonymous to the meaning of marginal value product from continuous function.

In order to avoid the confusion between MVP_{LP} and MVP_{cf}, the term "shadow price" rather than MVP_{LP} is used to indicate the marginal contribution to income of the last unit of resource in linear programming. Only resources which are limiting in use or those which have positive salvage prices have positive shadow prices. Hence the shadow prices of resources indicate which resources are restricting and the potential gains in income through acquiring one unit of limiting resources.

It should be noted that the shadow prices of resources indicate the pressures to expand or contract the use of a specific resource. Moreover, these pressures tell how far adjustments shouldbe made and the range over which these shadow prices hold.

The shadow prices of the excluded activities indicate the income penalties of forcing one unit of non-basis activities into the solution. The shadow prices of excluded activities are always positive because if the excluded activities were brought in with the given resource constraint, they would have to replace some higher earning activities already in the program.

The shadow prices for selected resources are presented in Table 4.5 for each representative farm. These values are the amount of income which the firm would gain or lose by purchasing or selling respectively one unit of the resource. As mentioned before, only scarce resources have positive values. The shadow prices for the cropland is much less than that in Model I. This result is to be expected as variation in restricting resources is allowed. In all farm situations, land is the most limiting resource as reflected by its high shadow price. The values range from $92 to $109 per acre for cropland and $62 to $79 per acre for rented land. The high shadow prices of cropland and rental land indicate that it would be profitable to expand farm size under assumed yields and price conditions.

The rental rate for cropland in the area was estimated to be around $30 per acre. The shadow prices of purchased land range from $38 to $50 per acre which are higher than a land rental rate. This indicates possible expansion in farm size through purchasing land at the price of $500 per acre under assumed product condition. The labor in season I (December to March) and in season 2 (April to May) is not exhausted. The labor in other seasons are most often limiting. However, an increase in the use of labor in these seasons would not be profitable except on the large and medium* farms.

Table 4.5. Shadow Prices for Selected Resources on Each Representative Farm (Model II)

Resources	Unit	Representative Farm			
		Small	Medium	Large	Medium*
Cropland	$/acre	101	95	92	109
Rented land	$/acre	71	65	62	79
Purchased land	$/acre	40	38	38	39
December, January, February, March Labor	$/hour	---	---	---	---
April, May Labor	$/hour	---	---	---	---
June-July Labor	$/hour	.50	1.51	3.26	3.49
August Labor	$/hour	.50	1.51	---	3.49
September, October, November Labor	$/hour	.50	1.51	3.26	3.49
Cash	$	.11	.09	.09	.16
Chattel Mortgage	$	.01	---	---	.05
Real Estate Mortgage	$	.02	.01	---	.07
Managerial Labor	$/hour	2.85	3.81	4.94	---

One of the limiting resources in the optimal solutions is the operating cash. However, the increase in cash beyond the initial amounts would not be profitable for all farms except medium* farms as its shadow price ranges from 9 cents to 16 cents per dollar. Managerial labor is a limiting factor in the optimum solutions except on medium* farms. But the increase in the use of this factor is undesirable as its shadow price ranges from \$2.85 to \$4.94 which is lower than its marginal factor cost.

In short, the shadow prices for resources indicate that land is the most limiting resource as reflected by its high shadow price. This indicates the farmer would likely find it profitable to expand farm size under the assumed prices and output conditions. At this point, it should be remembered that an expansion of land would not increase for all successive unit of land, since some other inputs might become limiting resources.

The shadow prices of an excluded activities indicate by how much income would be penalized were they forced into the final solutions. Therefore, the shadow prices of the non-basis activities indicate the competitive positions of these activities in the optimal solution. The lower the shadow prices of a non-basis activity, the higher is its competitive position in the optimal farm plan. On the contrary, the higher the shadow prices, the lower is its competitive position in the optimal organization.

In order to examine the effects of rotations on economic potential of all crop activities included in the model, the shadow prices of the excluded (or non-basis) crop rotation activities are presented in Table 4.6.

As shown in the table, COW, CCCBW and CCCCS rotations

Table 4.6. Shadow Prices of One Unit of Excluded Crop Rotations (Model II)

Crop Rotation	Unit	Representative Farm			
		Small	Medium	Large	Medium*
		Dollars			
CB	$/2 acres	8.85	13.25	7.18	NA
CS	$/2 acres	36.54	24.64	32.76	32.52
WB	$/2 acres	NA[1]	NA	NA	NA
WS	$/2 acres	26.21	10.15	24.42	30.35
CBW	$/3 acres	1.99	9.20	2.93	3.60
CBS	$/3 acres	17.94	.77	12.38	3.02
COW	$/3 acres	---	---	3.26	1.91
BCO	$/3 acres	25.08	21.65	29.16	12.76
CBO	$/3 acres	20.06	16.66	24.19	7.61
SCO	$/3 acres	22.20	---	24.98	14.29
CCB	$/3 acres	14.18	25.15	12.61	8.72
CCS	$/3 acres	7.14	---	5.15	4.20
CCCB	$/4 acres	6.57	25.45	6.87	.71
CCCS	$/4 acres	3.57	3.68	2.57	2.10
CCBW	$/4 acres	3.57	17.99	5.44	6.78
CCOW	$/4 acres	.25	3.25	---	---
CCBS	$/4 acres	18.57	8.67	14.20	5.42
CCCBW	$/5 acres	---	21.67	2.86	4.68
CCCCS	$/5 acres	---	7.36	NA	---
CCCBS	$/5 acres	15.83	13.11	12.20	3.97

[1]NA denotes does not apply.

are in the most competitive position in the optimal plan on the small farm as reflected by the near zero shadow prices for these activities. On the other hand, CS rotation is in the weakest competitive position as reflected by its shadow price of $36.54 per unit (2 acres) of crop rotation. This value is a net marginal cost (i.e., the excess of marginal cost over marginal revenue) indicating that the income would be reduced by $36.54 if one unit (2 acres) of CS rotation was forced into the final solution under assumed prices and yield conditions. It is worth noting that the competitive position of the same crop rotation changes as farm size changes. For example, CCCBW rotation is in the most competitive position on a small farm, but it becomes less competitive on the medium farm. On the medium farm, COW, SCO and CCS rotations are in the most competitive position as revealed by the near zero shadow prices of these activities. CS rotation still remains in the weakest competitive position as it was on the small farm. On the large farm, CCOW rotation is in the most competitive position while CS rotation is in the weakest competitive position in the final organization. This information is very important to a farmer in making decisions about selecting rotations because it not only indicates what rotations are not profitable but how much personal preference might be worth if a farmer preferred to force an excluded rotation into the solution.

Optimum Organizations Under Various Levels of Land Supply (Model II)

From the previous discussion, it appears that crop production is limited by the supply of land as reflected by the high shadow prices of cropland, rented land and purchased land. The resulting optimal solutions for all farm situations call for expansion of farm size up to the limit of land restriction permitted in the model. To further investigate the effect of variable land supplies on optimal land use, the opportunity to rent and purchase additional land is considered in this section. At the same time, two cases in which less land is available for rent and purchase are also considered in order to examine how optimum land use changes under more restricted land supply conditions. The initial levels of resources are the same as used in the Model II in the previous section.

Five cases are involved in the model based on the assumptions made in terms of potential land resources available for a farmer to rent and/or to purchase. The levels of potential land rentals and purchases assumed for each case in Model II are shown in Table 4.7. In this table, land A is defined as land which can be purchased at price of $500 per acre or can be rented at the annual rate of $30 per acre. These prices are based on what farmers thought they would have to pay for the land that was available for rental or purchases at the time of interview. The price of land B, on the other hand, was set at $600 per acre or can be rented

Table 4.7. The Levels of Potential Land Rentals and Purchases Used in Each Case in Model II[1] (Unit: Acres)

		Case I[2]				Case II				Case III				Case IV				Case V			
		S	M	L	M*	S	M	L	M*	S	M	L	M*	S	M	L	M*	S	M	L	M*
Land A[3]	Renting Limit	30	30	30	30	50	50	50	50	134	184	131	213	134	184	131	213	134	184	131	213
	Buying Limit	30	30	30	30	50	50	50	50	117	82	54	114	117	82	54	114	117	82	54	114
Land B[4]	Renting Limit	NA[5]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	200	300	200	1200	1500	2000	1500
	Buying Limit	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	200	300	200	1200	1200	1300	1200

[1]The levels of land A in Case III, IV, V are determined by the field survey data in 1972 while the others are assumed quantity.

[2]S stands for small; M stands for medium; and L stands for large.

[3]Land A: land which can be purchased at the price of $500 per acre or can be rented at the annual rate of $30 per acre.

[4]Land B: land which can be purchased at the price of $600 per acre or can be rented at the annual rate of $35 per acre.

[5]NA denotes does not apply.

at the annual rate of $35 per acre. The levels of land resource restriction in all cases were set by assumption except the quantity of land A in Case III, IV and V which were obtained from data collected from the field survey. In Case IV, and V, land B restrictions and activities were added. The levels of land B restriction in Case IV and V for each category of representative farms are shown in the table. The purpose of this relaxation on the land resource restriction is twofold: (1) to examine the effect of change in land resources on the optimal crop rotation and (2) to figure out what resources would become restrictive on expansions in farm size.

In this section, only the results for the large size representative farm in each case are presented. The programming results of the other representative farms in each case will be placed in Appendix B.

Table 4.8 presents the summary of optimum land use, the resource transactions and the shadow prices of farm resources for large farms under various levels of land resource availability. It is easily seen that the increase in land availability results in an increase in farm size and farm income and changes the optimum combination of crop rotations, although product prices are unchanged. The increases in farm size and net return are moderate in Cases I, II and III in which land is more restricted. However, farm size and net return increased considerably in Case IV and V as more land was assumed. In all cases, the WB rotation dominates in the optimal solutions with levels of WB rotation increasing as more land was obtained. Also other crop rotations entered the optimum plan as more land was acquired. For example, CCCB rotation entered the optimum solutions in Case I and II but moved out of the optimum organization when more land was allowed. The CCCCS rotation appeared in the optimum plans in Case III and IV while CCS rotation entered the optimum solution in Case V.

The amount of credit varied directly with farm size. The amounts of credit used increased as more land was obtained except in Case V in which case the amount of credit acquired decreased as farm size increased. The main reason for this is that the optimal solution in Case V did not call for the land purchasing activities which require more borrowed credit. As shown in the upper part of the table, land is acquired through renting 131 acres of land A and 700 acres of land B but no land is purchased.

A comparison of the optimal use of specific resources for five cases is also given in the table. There was no managerial labor requirements in Case I and Case II but a substantial managerial labor was required when more land was obtained (see Cases IV and V).

In all cases, some unskilled labor was required. The amount of hired seasonal labor increased as more land was acquired. The resulting optimal plans in all cases indicated that both family members and the operator took off-farm employment up to the limit permitted in the model. The

Table 4.8. Summary of Optimum Land Use, Resource Transactions and Shadow Prices Under Various Levels of Land Resources on Large Cash Grain Farm (Model II)

	Unit	Case I	Case II	Case III	Case IV	Case V
Net Return	$	74,164	77,195	83,783	100,586	117,926
Crop Rotation						
WB	acre	460	460	496	701	998
CCCB	acre	41	78	---	---	---
CCCCS	acre	---	---	127	253	---
CCS	acre	---	---	---	---	271
Credit Used	$	12,284	24,734	34,380	95,076	86,445
Resources Obtained or Sold						
Managerial Labor Hired	hour	---	---	130	1,793	3,339
Unskilled Labor Hired	man hrs	20	161	366	1,041	1,946
Managerial Labor Sold	hour	587	587	587	587	587
Family Labor Sold	hour	411	411	411	411	411
Land A Rented	acre	30	50	131	131	131
Land A Purchased	acre	30	50	54	54	---
Land B Rented	acre	NA[1]	NA	NA	300	700
Land B Purchased	acre	NA	NA	NA	31	---
Woodland Cleared	acre	---	---	---	---	---
Plowable Pasture Cleared	acre	3	---	---	---	---
Shadow Prices						
Cropland	$/acre	119	117	92	82	35
Land A for Rent	$/acre	89	87	62	52	5
Land A for Purchase	$/acre	66	64	38	14	---
Land B for Rent	$/acre	NA	NA	NA	47	---
Land B for Purchase	$/acre	NA	NA	NA	---	---
April-May Labor	$/hour	---	---	---	1.04	4.83
June-July Labor	$/hour	3.26	3.26	3.26	3.46	5.00
August Labor	$/hour	---	---	---	3.46	5.00
September-November Labor	$/hour	2.38	3.26	3.26	3.46	5.00
Cash	$	.09	.09	.09	.15	.67
Chattel Mortgage	$	---	---	---	.04	.51
Real Estate Mortgage	$	---	---	---	.06	.53
Managerial Labor	$/hour	---	---	4.94	4.78	6.36
Woodland	$/acre	---	---	---	---	---
Plowable Pasture	$/acre	---	---	---	---	---

[1] NA denotes the item is not applicable.

operators were allowed 587 hours of off-farm employment while the family members were permitted to work off the farm 411 hours per year at the wage rate of $5.75 per hour for an operator and $2.55 per hour for family members.

The optimal plan in all cases rents and purchases land A up to the land rental and land A purchase limits except in Case V where no land is purchased. When more land is available for rental in Case V, both land A and land B are rented in the optimal solution but no land is purchased. This clearly indicates that renting land is more profitable than purchasing land for agricultural use if abundant land is available for rent.[6] However, care has to be taken when this result is applied. Land may have other values that were not considered in the model. These values include purchasing land for inflation protection, capital gains, urban or industrial uses or simply for prestige.

No woodland is cleared in any case investigated. This indicates that converting woodland into cropland at the cost of $500 per acre is not economically justified under the assumed prices and product conditions. This result is consistent with the real situation in the sense that most farmers visited indicated that they had no intention to clear woodland due simply to the high clearance cost. However, they also indicated that the woodland could be cleared if the government could subsidize a part of the clearance cost. The

[6]The annual rental rate of $30 per acre used in this study is low compared to the land price of $500 per acre.

amount of subsidies desired varied between $200 and $300 per acre depending on the amounts of initial clearance cost.

The programming results show that no plowable pasture land is cleared in all cases except in Case I in which only 60 acres of land is permitted to be rented and purchased. This indicates that some plowable pasture land or low-cost-woodland[7] is likely to be cleared at the cost of $395 per acre[8] for cropland if product prices remain high and little land is available for rental and for purchase. This result is consistent with the current trends on a south central Michigan farm. In many cases, plowable pasture land and low-cost woodland were cleared at costs below $395 per acre in 1972 by a farmer who had little opportunity to acquire land by renting and/or through purchasing.

The shadow prices for selected resources are presented in the lower part of Table 4.8. Reading across the table, one can observe the effect of changing the levels of land resource availability on shadow prices of various resources. The shadow price of land decreases without exception as more land is obtained. For example, when the level of land availability was fixed at 60 acres in Case I, cropland had a value in use of

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[7]Low-cost woodland is defined as woodland which can be cleared at the cost of $395 or less per acre.

[8]Among the $395, the clearance cost accounts for $245 per acre and tiling cost $150 per acre; thus drained and cleared plowable pasture can be brought into crop production merely by covering the opportunity cost of using it for pasture which is not more than $20 per acre. (See R. L. Meekhof, L. J. Connor and S. B. Nott, "Field Rental Rates in Michigan," Extension Bulletin, E-683-Rivised May 1974).

$119 per acre but its shadow price dropped all the way down to $35 per acre in Case V where land was more abundant.

On the other hand, the shadow prices of other resources increased consistently as more land is acquired. It is obvious that in linear programming, the shadow price of a restricting resource increases as the amount of another resource is increased. It should be remembered that the shadow price of a resource indicates the contribution to optimum income of the last unit of resource. Thus the twofold effect of the operation of the law of diminishing returns is demonstrated in linear programming. The same phenomena can also be observed on other representative farms (see Table B-1 to B-3 in Appendix B).

Examination of the shadow prices of various resources in Case V where land was abundant, revealed several conclusions about potential expansions in farm size.

The very low shadow prices on rental land and zero shadow price for purchased land indicate that it would not be profitable to expand farm size along the extensive margin. It also implies that land resource is no longer a limiting factor in the optimal solution.

On the other hand, the high shadow price on credit indicates that it would be profitable for a farmer to borrow such credit if further sources of credit were made available at the prevailing rate of interest.

The comparatively high shadow price of labor (including managerial labor) indicates the desirability of increasing in the use of labor in optimal solution. It also indicates that labor is in short supply.

Judging from the high shadow prices of labor and capital in Case V, it is obvious that these two factors are the main resources that restrict the further expansion of farm size.[9]

The desirability of expanding farm size as shown by the programmed solutions imply that (1) land values in the studied area will continue to be bid up as farmers are seeking more land for farming; (2) inasmuch as farm sizes tend to be stable, the land price of $500 per acre and the annual rental rate of $30 per acre used in this study was too low for land for farming purposes and (3) more unused cropland, and plowable pasture land are expected to be brought into cultivation if product prices remain high with stable input prices. Since quite a few acres of land were either diverted by government set-aside programs or simply idle in 1972, an increase in crop area by expanding the extensive margin of cultivation was indicated as likely to occur after the termination of the government production control programs. In fact, this has taken place.

However, the programmed results indicate that farm size in the studied area would not be expected to expand without limit even under conditions of plentiful land supply. Along with the rise in land values, labor (including managerial labor) and capital would eventually become the main restricting resource to limit the further expansion of farm size.

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[9]The same analysis can be applied to the other representative farms (see Table B-1 to B-3 of Appendix B).

The shadow prices of a unit of excluded crop rotations in each case are presented in Table 4.9.

It should be noted that the value imputed to excluded or non-basis activity indicates the amount by which the optimum income would be reduced if one unit of that activity were forced into the optimum solution. Therefore, one can easily identify close competitors to those activities in the optimal organization. The nearest competitive rotations in Case I are CCOW and CCCCS as shown by their near zero shadow prices.

Reading across the table, one can observe the change in competitive position of a unit of each crop rotation as more land is acquired.

It is interesting to note that the competitive position of a crop rotation changes as farm size increases. However, the direction of change is not the same for each crop rotation. Some crop rotations become more competitve while the others less competitive when a farm is permitted to acquire more land. For instance, CB rotation loses its competitive position consistently as more land is obtained. This is indicated by its increasing shadow price as more land is supplied.

In contrast, WS rotation becomes more competitive as more land is obtained. This is shown by its consistently decreasing shadow price as farm size increases. Also, one can observe that CCOW rotation remains the most competitive position while CS rotation appears the least competitive position in all cases.

Table 4.9. Shadow Prices of a Unit of Excluded Crop Rotations Under Variable Land Resource Level on Large Cash Grain Farm (Model II)

Crop Rotation	Case I	Case II	Case III	Case IV	Case V
CB	.74	.82	7.18	5.23	11.31
CS	33.98	33.99	32.76	30.58	32.35
WS	32.09	32.01	24.42	23.31	12.15
CBW	2.71	2.67	2.93	4.11	7.12
CBS	6.79	7.06	12.38	6.15	3.81
COW	3.53	1.90	3.26	6.00	12.53
BCO	15.03	15.60	29.16	26.21	43.33
CBO	10.06	10.63	24.19	21.09	36.99
SCO	17.93	18.55	24.98	21.04	27.01
CCB	5.95	5.99	12.61	14.13	40.98
CCS	5.58	5.66	5.15	3.13	NA
CCCB	NA[1]	NA	6.87	7.00	16.86
CCCS	2.79	2.83	2.57	1.57	.09
CCBW	5.01	4.92	5.44	7.92	14.00
CCOW	---	---	---	---	---
CCBS	8.37	8.59	14.20	8.25	.93
CCCBW	2.22	2.09	2.86	6.35	14.09
CCCCS	---	---	NA	NA	.18
CCCBS	6.18	6.36	12.20	8.14	10.34

[1]NA denotes the item is not applicable.

Optimum Organizations Under Various Price Combinations (Model II)

This section presents the resulting optimal solutions of representative farms under a number of different price combinations. Model II is used to investigate the effect of change in prices on land use, scale of operation and farm income.

The initial resources are the same as those previously used in the Model II except the assumption made for the land availability for rental and/or purchase. The assumed quantity of land for rent was 50 acres and the quantity for purchase was 50 acres.

Five different product price combinations were studied for corn, soybean, wheat, oats and field beans as presented in Table 4.10.

In each case, price ratios among products are different as the same optimum plans would result if constant price relationships were maintained among products and inputs.

Results are presented here only for the large size representative farm situations. The results of the other representative farms are in Appendix B. Table 4.11 presents a summary of optimum land use, resource transactions and shadow prices of selected resources for large farms for the five price combinations. Reading across the table, one can observe the effects of price variations on the optimum farm organization in terms of net returns, levels of specific crop rotations and credit used.

Table 4.10. Levels of Product Prices Assumed in Each Case (Model II)

Product	Unit	Case I[1] (Low Price)	Case II (Fall 1973 Price)	Case III[2] (High Price)	Case IV[3] (Low Wheat Price)	Case V (Farmer's Desired Price)
Corn	Bu.	$ 1.80	$ 2.25	$ 2.48	$ 2.25	$ 2.34
Soybean	Bu.	4.40	5.50	6.05	5.50	5.34
Wheat	Bu.	2.13	4.25	4.25	3.00	4.03
Oats	Bu.	.90	1.25	1.38	1.25	1.49
Field Beans	cwt.	12.00	15.00	19.50	15.00	18.09

[1]Prices of corn, soybean, oats and field beans are 20 percent lower and wheat price is 50 percent lower than those in Fall 1973 price.

[2]Prices of corn, soybean, oats are 10 percent higher, and field beans 30 percent higher than those in Fall 1973 price.

[3]All product prices are the same as those in Fall 1973 price except wheat price at $3.00 per bushel.

Table 4.11. Summary of Optimum Land Use, Resource Transaction and Shadow Prices for Selected Resources on Large Cash Grain Farm (Model II)

Price Combination	Unit	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
Net Return	$	51,068	77,195	96,500	72,248	87,928
CBS	acre	446	---	---	280	---
CB	acre	92	---	284	258	284
WB	acre	---	460	269	---	269
CCCB	acre	---	78	---	---	---
Credit Used	$	30,288	24,734	34,072	33,309	34,072
Resources Acquired						
Managerial labor hired	hour	---	---	---	---	---
Unskilled labor hired	Man hour	334	161	301	404	301
Land rented	acre	50	50	50	50	50
Land purchased	acre	50	50	50	50	50
Woodland cleared	acre	---	---	---	---	---
Plowable pasture cleared	acre	---	---	15	---	15
Off-Farm Employment						
Managerial labor	hour	587	587	587	587	587
Family labor	hour	411	411	411	411	411
Shadow Prices						
Cropland	$/acre	70	117	135	91	129
Rented land	$/acre	40	87	105	61	99
Purchased land	$/acre	17	64	82	37	75
April-May Labor	$/hour	3.26	---	---	3.26	---
June-July Labor	$/hour	---	3.26	3.26	3.26	3.26
August Labor	$/hour	---	---	---	---	---
September-November Labor	$/hour	3.26	3.26	3.26	3.26	3.26
Cash	$	.09	.09	.09	.09	.09
Chattel Mortgage	$	---	---	---	---	---
Real Estate Mortgage	$	---	---	---	---	---
Managerial Labor	$/hour	---	---	3.36	2.09	1.67
Woodland	$/acre	---	---	---	---	---
Plowable Pasture	$/acre	---	---	16	---	9.53

In Case II (i.e., under Fall 1973 prices), the optimal solution includes 460 acres of WB rotation and 78 acres of CCCB rotation. However, wheat is not in the optimal solution for Case I where wheat price is relatively low.

In Case III where field beans have a strong price advantage, CB and WB rotations enter the optimum plan. Wheat leaves the optimal organization at $3.00 per bushel with other crop prices constant at Fall 1973 prices as shown in Case IV. The need to borrow to attain optimal organizations is also shown in the table.

One of the interesting price combinations is the farmer's desired price as indicated in Case V. As part of the survey, data were collected from the farmers concerning the product prices that would induce farmers to bring more unused land (including woodland and plowable pasture land) into cultivation. At this price combination, the programming results show that plowable pasture land was cleared up to the limit permitted by the model. This result tends to justify what farmers thought to be appropriate prices to give them an incentive to bring more land into cultivation.

Specific resources acquired and their shadow prices for the large farm are also presented in the table. No additional managerial labor is acquired in any case; however, some seasonal labor is required to attain the optimum solution. The amounts of unskilled labor required range from 161 to 404 man hours.

In all cases, the farmer rents and purchases all the available land and increase crop acreages. No woodland is cleared; however, 15 acres of plowable pasture land is cleared at the cost of $395 per acre in Case III (i.e., high price) and Case V (i.e., farmer's desired price). This indicates that under higher product prices and more restricted land supply conditions, plowable pasture land and low-cost woodland would likely be cleared and converted to a cropland.[10]

Both family members and operator worked off-farm up to the limits of the restrictions. The results are consistent with what cash grain farmers were doing in the south central area in 1973.

The shadow price of land varies directly with the change in product price, i.e., shadow price of land increases as product prices increase. The shadow price of land indicates that it would be profitable to expand farm acreage under the assumed prices and output conditions. In most cases, June-July labor and September-November labor were limiting resources, but August labor was not exhausted.

In all cases, the capital is not a restricting resource under the assumption that up to 50 percent of real estate assets may be mortgaged. This is reflected by the zero shadow prices of chattel mortgage and real estate mortgage credit.

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[10]This result is consistent with the real situation. In many cases, this has actually occurred on farms in south central Michigan.

The shadow prices of a unit of an excluded rotation under various price combinations are presented in Table 4.12.

Reading across the table, one can observe the change in competitive position of a unit of each crop rotation when product price changes. In Case I where all product prices are lower than 1973 fall price, WB and CBO rotations are in the most competitive position as reflected by the near zero shadow prices for these activities. The shadow prices for WS rotation is $37.77 indicating that it is in the least competitive rotation.

In contrast, in Case III where all product prices except wheat are higher than the 1973 fall price, CBS and CBO rotations are on the verge of coming into the program as indicated by the near zero shadow prices for these activities. The shadow price of CS rotation is $50.96 which indicates that the rotation is the most expensive to force into the optimum plan. The shadow prices of the other crop rotations can be interpreted in a similar way.

Application and Limitations of the Model

Some remarks should be made concerning the application of the results derived from this study. In the first place, the assumptions concerning credit supplies in the model are based on the usual practices of institutional lenders. No provisions were made in the model for internal credit rationing due to uncertainty. In reality, farmers may prefer a much lower ratio of debts to total assets than

Table 4.12. Shadow Prices of One Unit of an Excluded Rotation Under Various Price Combinations--Large Farm (Model II)

Crop Rotation	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's (Desired Price)
CB	NA[1]	.82	NA	NA	NA
CS	32.47	33.99	50.96	34.20	46.10
WB	---	NA	NA	---	NA
WS	37.77	32.01	49.80	33.16	44.94
CBW	13.45	2.67	19.30	9.68	16.74
CBS	NA	7.06	---	NA	---
COW	14.48	1.90	26.18	6.94	21.07
BCO	4.97	15.60	4.97	4.97	4.97
CBO	---	10.63	---	---	---
SCO	13.29	18.55	19.17	9.52	16.61
CCB	15.95	5.99	21.80	12.18	19.24
CCS	20.99	5.66	32.70	13.46	27.58
CCCB	20.74	NA	32.44	13.20	27.33
CCCS	28.94	2.83	46.50	17.64	38.83
CCBW	26.48	4.92	38.22	18.95	33.10
CCOW	34.80	---	52.42	23.50	44.75
CCBS	6.23	8.59	18.77	4.58	16.21
CCCBW	34.43	2.09	52.02	23.13	44.35
CCCCS	34.77	---	66.52	22.10	56.29
CCCBS	20.86	6.36	32.57	13.33	27.46

[1]NA denotes does not apply.

the limits imposed by lending agencies. These facts were repeatedly indicated by the farmers interviewed. Consequently, the actual demand for land and associated durable assets may be much less than those indicated.

Secondly, the model does not consider the overall aggregate effects of large scale adoption of the results on product and input markets. The optimal solutions in the model call for expansion of farm size and associated durable assets to produce specific crops. However, if all farmers bid for resources, land and associated input prices would increase while product prices would likely decrease. This trend would limit the expansion of farm size. Thus, in reality the farm size would be smaller than that indicated in optimal plans.

Lastly, the model assumed that farmers possess perfect knowledge. However, as perfect knowledge does not exist in the real world, risk and uncertainty would affect adjustment of land use, enterprise levels and farm size.

Some of the limitations of this study should be noted. Problems concerning the stock and flow characteristics of resources are not sufficiently handled by this model. As was shown in the model, the acquisition and salvage of durable assets are measured in terms of stock unit. However, the productivity of the stock stems from the flow of services generated by the stock. The objective functions for acquisition and salvage activities are for services per production period with the ratio of flow to stock determined by the utilization of the flow in production activities.

The stock and flow conversion problem is closely related to the user cost problem which was not handled in this study. Solution of the user cost problem could probably destroy the independence of activities to make it impossible for a linear programming to handle investment and disinvestment.

The unrealistic assumptions such as perfect divisibility, linearity in the input-output coefficients and single-value expectations built in the model continue to be a problem.

The optimal solutions obtained from a linear program are restricted to the particular activities or alternatives covered in the model. As previously mentioned, the determination of the factor combinations within each alternative is exogenous to the model. Erroneous combination of factors within the alternatives would result in erroneous solutions from the model. The land price of $500 per acre and annual rental rate of $30 per acre assumed in the model are considered too low.[11] As such, the consequent programming result is the expansion of farm size for all representative farms by renting and/or through purchasing land up to the limit permitted by the model. Land often becomes

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[11]The land price reported by farmers were probably lower than what they would have actually to pay when they purchase land for farming purposes.

the most limiting resources as reflected by its high shadow price. On the other hand, the plowable pasture clearance cost ($395 per acre) used in the model is too high. As a result, plowable pasture was cleared only under high product price and more restricted land supply conditions. Age of an operator and his desire to increase farm size are not adequately handled in the model. No provision was made to limit the expansion of farm size for an old operator. Wage rate of off-farm work for old farmers was assumed as same as that of young farmers which did not correctly reflect the real situation to some extent.

The optimum solutions are affected by the assumptions made relative to available off-farm employment. The model assumes off-farm employment is available only for a specified number of days in five seasons. Full-time off-farm employment should be permitted so that one could investigate which farms would go out of business.

In applying the results of this study, the above mentioned limitations have to be kept in mind and the careful interpretation must be made.

Summary

The objective of this chapter was to ascertain profitable adjustments in the farm organization and land use for cash-grain farms in south central Michigan in response to the increasing demand for agricultural products.

Linear programming was used to determine optimum farm plans under (1) farm resources fixed at initial level, (2) land, labor and machinery investment variable and (3) product prices variable. Investment/disinvestment theory was incorporated into situations (2) and (3) though the user cost problem remained unhandled.

Cash grain farmers were classified by their desire (or willingness) and ability to make farm organization adjustments. One variable, age of operator, was used to represent homogeneity with respect to willingness to make adjustments. Another variable, net worth, was used to represent homogeneity in terms of ability to make changes. Thus, farmers were stratified by age of operator and net worth as a major determinant for setting up representative farms. Two age classifications were: 24 to 55 years and over 55 years. Three net worth classifications were $30,000 to $80,000, and $80,000 to $150,000 and over $150,000 which were defined respectively as small, medium and large farms.

The analysis was first given for Model I with cropland and associated durable resources fixed at 1972 levels. Secondly, the optimal organization was presented for Model II which permits variation in the land resources and associated durable assets. Emphasis was placed on the effects of change in land resource availability on optimal land use, farm organization and competitive position of each crop rotation. Lastly, the programmed solutions were given for Model II under a number of different price combinations. Application and limitations of the model were discussed in the last part of the chapter.

CHAPTER V

FUNCTIONAL ESTIMATION OF RESOURCES PRODUCTIVITY

This chapter presents the statistical results of fitting the production function and the resulting estimates of resources productivity. As previously mentioned, the Cobb-Douglas function was employed to estimate the value productivity of the various categories of inputs and investments. Three separate functions were fitted to the data gathered from sixty-one cash grain farms. In each case, somewhat different estimates of value productivity resulted for each category of inputs and investments. However each fit provided valuable information which was used to obtain more realistic estimates of marginal value productivities for various inputs and investments.

The Data

The data obtained from each of the sixty-one farms for the calendar year of 1972 were as follows:

The dependent variable was Y, or gross income, and the independent variables were:

X_1, land, in tillable acres,

X_2, labor, in months,

X_3, productive operating expenses, in dollars,

X_4, machinery investment, in dollars,

X_5, buildings, in dollars.

Gross income (Y) included all crop income from productive resources for the year 1972. Income from livestock was excluded; however, crop production utilized by livestock was credited as gross income. Land and pasture rent, custom work or machinery rent were also included in gross income since they represented a return to productive factors on a farm. Such sources of income as government soil bank payments, subsidies, rental values of the farm home and investments in other business were not included.

The landlord's share was credited to gross income in the case of crop-share renting and the corresponding input share on the part of the landlord was included in the appropriate input categories. In the case of cash rent no charge to expenses was made as the rented land was included in the tillable acres.

The prices used in computing the value of farm products were the average prices for each crop in Michigan in 1972.[1] These prices per bushel were: $1.12 for corn; $3.27 for soybeans; $1.62 for wheat and $.76 for oats. Other prices were: $10.53 per cwt for dry beans and $29.96 per ton for hay.

Land (X_1) was measured in actual tillable acres used in crop production. Diverted tillable acres, soil bank land, unoperated cropland, land for pasture, woodland, ditches and farm building lots were excluded.

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[1]Sources of Data: Michigan Agricultural Statistics, Michigan Department of Agriculture, July 1973, p. 40.

Labor (X_2) was measured in man-month equivalents used on the farm with regard to crop production including custom work, machinery maintenance and crop storage. Labor furnished with hired machine custom work, labor used in connection with livestock, and unproductive labor was excluded as its value is in productive operating expenses.

Productive operating expenses (X_3) included all inputs that would be expected to yield at least one dollar return for each dollar spent. These inputs included custom work or machinery hired, fertilizer and lime cost, power and machinery and seed cost, etc. In order to avoid double accounting, machinery depreciation and machinery maintenance charges such as tire purchases and major overhauls were excluded from operating expenses. Furthermore, insurance, interest and tax charges were excluded, since they were not considered productive expenses. This means that the earning power of machinery, land and operating expenses must cover such charges. In computing fertilizer cost, the residual values were subtracted from 1972 expenses if these expenses were much larger than those for a normal year.

Machinery and equipment investments (X_4) were valued at what a farmer thought they were worth in farming in early 1972. Values to farmers are ordinarily greater than salvage or sale values, but less than the replacement costs of machinery of the same age, quality and condition. Machinery and equipment used for livestock production was excluded as was livestock income.

Building investment (X_5) was estimated in a similar method as used in measuring machinery investment. Buildings idled or those used for livestock were excluded.

Fitting the Production Function

The data gathered from the sixty-one sample farms were used as a basis for three regression analyses. The first equation includes five variable input categories, i.e. land, labor, operating expenses, machinery investment and buildings. In the second equation, buildings were omitted in an attempt to obtain more reliable estimates of the remaining production coefficients. In the final equation, a restriction was imposed which made the sum of the regression coefficients equal to one; this restriction imposed constant return to scale.

The First Equation

The data collected from the farms were first summarized in the categories of gross income and the variable inputs described previously. These figures were then converted to the logarithm form, and fitted to a Cobb-Douglas production function.

The estimated regression coefficients, together with the relevant statistics, are shown in Table 5.1.

In the logarithmic form, the estimated Cobb-Douglas function was:

Table 5.1. Regression Coefficients and Related Statistics of the Estimated Production Function (61 Farms)

Variables	Regression Coefficients ($\hat{b}_i$)	Standard Error of Coefficients ($S_{\hat{b}_i}$)	T-Statistic for Testing $H_o : b_i = 0$
Constant terms	1.28665	0.25522	5.0414
Land, acre (X_1)	0.51261	0.08834	5.8024
Labor, month (X_2)	0.25830	0.06589	3.9203
Operating expenses, Dollar (X_3)	0.24728	0.11443	2.1610
Machinery investment, Dollar (X_4)	0.09279	0.08910	1.0414
Buildings, Dollar (X_5)	0.06343	0.04727	1.3418

Multiple correlation coefficient, R = 0.9601

Coefficient of determination, R^2 = 0.9217

Sum of regression coefficients, 1.17441

$$\text{Log } Y = 1.28665 + .51261 \log X_1 + .25830 \log X_2 + .24728 \log X_3 + .09279\, X_4 + .06343 \log X_5.$$

The estimated regression coefficients, b_i, indicate the percentage change in gross income associated with a one percent change in factor inputs. For example, one percent increase in cropland is accompanied by a 0.51261 percent increase in gross farm income; a one percent increase in farm labor is associated by a 0.25830 percent increase in gross farm income.

The sum of the regression coefficients was 1.17441, indicating increasing returns to scale, i.e. with an increase in all factors by one percent, gross income would increase by more than one percent (1.17 percent). A test of significance indicated that the results differ significantly from 1.00 (constant returns) at a five percent probability level. A significance test of the sum of the regression coefficients will be discussed in more detail in the following section.

The multiple correlation coefficient was 0.9601, indicating that the correlation between the dependent variable and the combined independent variables was fairly high. The coefficient of determination (R^2) was 0.9217, which suggests that 92.17 percent of the variation in the logarithm of the estimated gross income was associated with variation in the independent variables included in the analysis. The remaining 7.83 percent of variance unexplained by the independent variable was likely due to such factors as weather conditions, timing, aggregation or index number problems, and differences in the appraised value of investments.

The estimate of the logarithm of gross income (log $\hat{Y}$) at the geometric mean was found to be 4.16800, or in natural numbers, 14,723 dollars.

The standard errors of estimate ($\hat{S}$) of the dependent variable (log Y) was 0.11866. This implies that under the production conditions prevailing in 1972, the logarithm of the actual average gross income (log Y) of the typical (geometric mean) farm would be expected to fall between 4.16800 ± 0.11866 in 68.27 percent of the sample, or in natural numbers, between $11,203 and $19,349. This also indicates that one farm out of three farms with the geometric mean organization would be expected to have a gross farm income of less than $11,203 or greater than $19,349.

The marginal value productivity of each factor input for a typical farm[2] is computed from the equation

$$MVP_{x_i} = b_i \frac{\hat{Y}}{\bar{X}_i}$$

Where:

MVP_{x_i} = the marginal value products of input X_i;

b_i = the regression coefficient of log X_i;

$\hat{Y}$ = geometric mean of gross farm income; and

$\bar{X}_i$ = geometric mean of factor input, X_i;

and are shown in Table 5.2.

From the equation of computing marginal value products, it is apparent that the reliability of marginal value products

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[2]The term "typical farm" is used to indicate a farm having geometric mean quantities of the input categories for the farms included in the study. A geometric mean is better than an arithmetic mean for studying a group of farms because it gives proportionately less weight to the few large farms included in the sample and tends to be more representative of the majority.

estimates are closely related to the level of significance of the regression coefficient.

Table 5.2. Estimated Marginal Value Products of Typical Organization Farms (Based on 61 Cash-Grain Farms in Clinton and Ionia Counties)

Input Category	Quantity of Input (Geometric Mean)	Regression Coefficient	Marginal Value Product (Dollars)
X_1 Land	142.08 acres	.51261	53.12
X_2 Labor	7.36 months	.25830	516.71
X_3 Operating Expenses	$5,265	.24728	.691
X_4 Machinery Investment	$16,886	.09279	.081
X_5 Buildings	$6,619	.06343	.141

One way to test the regression coefficients for significance is to test the coefficients against zero as a null hypothesis using t-test. The regression coefficients were significantly different from zero at the .05 percent level for land (b_1) and labor (b_2), five percent level for operating expenses (b_3), and were not significantly different from zero at the five percent level of significance for machinery (b_4) and building (b_5) investments.

A better way to test the significance of the coefficients is to compare the estimated coefficients with the coefficients necessary to yield marginal value products equal to a set of minimum reservation prices or returns for those factors.

On the basis of observation and discussion with farmers, extension workers and farm management specialists, the following were considered as reasonable minimum expected reservation prices or returns:[3]

Land	medium quality	$41.00 per tillable acre
	good quality	$50.00 per tillable acre
Labor	family labor	$400.00 per month
	operator's labor	$500.00 per month
	Entrepreneurial labor	$833.00 per month
Operating Expenses		$1.04 per $1.00 of expense
Machinery Investment		25 percent
Building Investment		10 percent

The minimum expected return to medium quality land was based on an eight percent interest charge for land valued at $400.00 per acre, plus seven dollars for taxes and two dollars for maintenance. Good quality land was valued at $500.00 per acre with the same interest rate, plus eight dollars for taxes and two dollars for maintenance for a reservation price of $50.00 per acre.

The minimum expected return to family labor and operator labor was based on a wage rate of $2.00 per hour for the former and $2.50 for the latter using eight hours a day, 25 days a month, as a basis for computation.

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[3]Dr. Glenn L. Johnson of the Department of Agricultural Economics of Michigan State University was very helpful in developing these minimum expected reservation prices.

The expected return to entrepreneur was based on a yearly income of $10,000.00. For operating expenses, a return of one dollar plus four percent interest (eight percent for an average investment period of six months) on current crop expenses was expected. The return to machinery investment must cover maintenance, depreciation, interest on investment, insurance and taxes. It was estimated that a twenty-five percent return on machinery investment was reasonable consisting of ten percent for depreciation, two percent for insurance, three percent for maintenance and ten percent for interest. The minimum return to buildings must cover five percent of depreciation and maintenance and five percent interest on investment.

The estimated minimum expected return was substituted for the MVP_{x_i} in the equation $\hat{MVP}_{x_i} = \frac{b\hat{Y}}{X_i}$. These equations were then solved for the coefficients which would yield these minimum expected returns. Table 5.3 compares these coefficients with the estimated regression coefficients.

As shown in the table, the estimated coefficients were lower than the coefficients required to yield minimum return for operating expenses, machinery investment and entrepreneurial labor. The differences were large enough to fall beyond the 68.27 percent confidence interval for cash expenses and the 95 percent confidence interval for machinery investment.

On the other hand, the estimated coefficients were higher than the coefficients required to yield minimum

Table 5.3. Comparison of Estimated b_i's and b_i's Necessary to Yield Minimum Marginal Value Products

Variable	Estimated b_i	Standard Error of Estimated b_i	b_i to Yield Minimum Return	Difference
Land, acre, X_1	0.51261	0.08834	0.39566 (MFC_{X_1} = 41)	0.11695
			0.48251 (MFC_{X_1} = 50)	0.03010
Labor, month, X_2	0.25830	0.06589	0.19996 (MFC_{X_2} = 400)	0.05834
			0.24995 (MFC_{X_2} = 500)	0.00835
			0.41642 (MFC_{X_2} = 833)	-0.16342
Operating Expenses, Dollar, X_3	0.24728	0.11443	0.37191 (MFC_{X_3} = 1.04)	-0.12463
Machinery Investment, Dollar, X_4	0.09279	0.08910	0.28673 (MFC_{X_4} = .25)	-0.19394
Buildings, Dollar, X_5	0.06343	0.04727	0.04487 (MFC_{X_5} = .10)	0.01856

return for land, operator and family labor and buildings. The differences, however, are small enough to fall within the 68.27 percent confidence intervals for land (compared at MFC_{X_1} = $50.00), operator and family labor and buildings.

The estimated coefficient for labor was lower than the coefficient required to yield the reservation price (entrepreneurial labor valued at $833.00 a month), that coefficient falling beyond the 95 percent confidence intervals.

The reliability of the estimated regression coefficients is affected by the correlations among the independent variables, the range of the independent variables and the sample size.[4] Such influences are accounted for in the standard errors of the regression coefficients.

Quite often, system of errors may exist, due to the high intercorrelations among the independent variables. In such cases, if the marginal value product of one input is overestimated the MVP of another is underestimated. The simple correlation coefficients were computed as in Table 5.4.

It is easily seen that the correlation between land (X_1) and operating expenses (X_3) is high. Lower degrees of correlation were found between operating expenses (X_3) and

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[4]Notes taken on lecture of production economics given by Dr. Glenn L. Johnson, Michigan State University, 1967. For a detail discussion see: Ezekiel, Mordecai, Methods of Correlation Analysis. New York: John Wiley and Sons, Inc., 1949, p. 502.

machinery investment (X_4), between land (X_1) and machinery investment (X_4), and between labor (X_2) and operating expenses (X_3).

Table 5.4. Simple Correlation Coefficients Between Each Input Category

	X_5 Buildings	X_4 Machinery Investment	X_3 Operating Expenses	X_2 Labor
X_1 (Land)	.50612	.77689	.8860	.50500
X_2 (Labor)	.41233	.55585	.67783	
X_3 (Operating Expenses)	.53894	.82816		
X_4 (Machinery Investment)	.66347			

Therefore, the estimated coefficients may involve compensatory errors for the above-mentioned pairs of inputs. In other words, for any set of inputs mentioned, one of the coefficients may be overestimated and the other underestimated compared to the true regression coefficients with corresponding errors in the marginal value product estimates obtained from the coefficients.

The estimated marginal value product for cash expenses appears low.[5] In view of the fairly high correlation existing between land and operating expenses (.89) and between

[5]The low earning power of cash expenses might be partly attributed to the high percentage (51 percent) of part-time

land and machinery investment (.78), it appears that the regression coefficient for land is overestimated with compensating underestimation of the coefficients for cash expenses and machinery. Thus the estimated marginal value products of cash expenses and machinery are regarded as low while the estimated marginal earning of tillable acres of land as high.

By the same token, the correlation between labor (X_2) and current expenses (X_3) may have caused the estimated marginal value product of labor to be high and the estimated marginal value product of operating expenses to be low. In using the results of this study to find profitable farm reorganization, these likely errors have to be taken into account.

The Second Equation

The reliability of the estimated marginal value productivity for building investments (X_5) was not high as indicated by the high standard errors of its coefficient (b_5). This is probably due to difficulty in measuring the value of buildings. The amount of farm building investment is not proportional to farm size though building investments were correlated with other inputs at simple correlations of .41

farms among 61 farms interviewed. Generally, a part-time farmer tends to spend more cash for inputs in order to have more time for off-farm work.

or higher. The correlation between farm gross income and buildings was comparatively low (γ_{yx_5} = .587).

In an attempt to obtain a better fit with greater confidence in the estimates of the regression coefficients, buildings (X_5) were then excluded. When buildings were omitted, the multiple coefficient of determination was reduced by only .0025, an insignificant amount. The estimated coefficients (b_i's) for the other inputs and the relevant statistics are shown in Table 5.5.

Table 5.5. Regression Coefficients and Related Statistics of the Estimated Production Function (61 Farms)

Variables	Regression Coefficients (b_i)	Standard Error of Coefficients	T-Statistics for Testing H: $b_i = 0$
Constant Terms	1.32195	0.25567	5.1706
Land, acre X_1	0.51541	0.08895	5.7945
Labor, month, X_2	0.26672	0.06605	4.0379
Operating Expenses, Dollar, X_3	0.23763	0.11501	2.0661
Machinery Investment, Dollar, X_4	0.14711	0.07994	1.8403

Multiple correlation coefficient, R = 0.9587

Coefficient of determination, R^2 = 0.9192

Sum of regression coefficients, 1.16687

The results of the t-test performed on the regression coefficients indicate that the estimated coefficients were different from zero at level of significance of .05 percent for land and labor, 5 percent for operating expenses and 7.1 percent for machinery investment. The multiple correlation coefficient is 0.9587, indicating the correlation between the dependent variable and all the independent variables is fairly high.

The coefficient of determination (R^2) is 0.9192, implying that the four explanatory variables specified in the model taken together explain 91.92 percent of the variation in gross farm income.

The sum of the regression coefficients was 1.16687, indicating increasing returns to scale since gross income would increase by more than one percent if all factor inputs were increased simultaneously by one percent. A significance test suggests that the sum differ significantly from one at a five percent probability level.[6]

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[6] In the Cobb-Douglas production function $Y_i = \beta_1 + \beta_2 X_{i2} + \beta_3 X_{i3} + \varepsilon_i$ where Y = log outout, X_{i2} = log labor input, and X_{i3} = log capital input, the hypothesis of constant returns to scale is equivalent to the hypothesis H_o: $\beta_2 + \beta_3 = 1$. In general, the hypothesis H_o: $\beta_j + \beta_k = a$ can be tested by noting that $(\hat{\beta}_j + \hat{\beta}_k - a)/S_{\hat{\beta}_j + \hat{\beta}_k} \sim t_{n-k}$ where $S_{\hat{\beta}_j + \beta_k} = \sqrt{S_{\hat{\beta}_j}^2 + S_{\hat{\beta}_k}^2 + 2 \text{ Est. Cov } (\hat{\beta}_j, \hat{\beta}_k)}$. This test can be

Based on the sums of coefficients of factor inputs and the result of statistical tests, increasing returns to scale seem to prevail in the sample studied. However, an attempt was made to further examine the result by dividing the sample farms into two size groups. A large farm was defined as one with 150 acres or more of cropland. Conversely, one with less than 150 acres was classified as a small farm.

The typical farm among the 30 large farms had a gross income of $38,279. It had 352 acres of land, 11.80 months of labor, $12,210 in operating expenditures and $35,700 in machinery investment. On the other hand, the typical organization among the 31 small farms earned a gross income of $8,866. The associated inputs included 85 acres of land, 7.97 months of labor, $3,302 in operating expenses and $10,692 in machinery investment. Cobb-Douglas production function was then fitted separately for each group of farms. The sums of estimated regression coefficients, together with the relevant statistics for two groups of farms, are shown in Table 5.6.

It is interesting to note that the sums of coefficients of the large and small farms reveal very distinct

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extended to a sum of more than two regression coefficients. See J. Kmenta, Elements of Econometrics. New York: The Macmillan Co., 1971, p. 372.

Table 5.6. Sums of Regression Coefficients and Related Statistics of the Estimated Production Functions for Large Farms (30) and Small Farms (31)

Farm Cateogry	Sum of Coefficients Σb_i	Standard Error of Σb_i $S_{\Sigma b_i}$	Degree of Freedom	T-Values for Testing H_o: $\Sigma b_i = 1$	Results of Test (5%)
Large Farm					
Average 352 Acres $38,279 11.8 months					
With Buildings	1.02892	.08089	24	.35749	Accept H_o
Without Buildings	.097978	.07824	25	-.25847	Accept H_o
Small Farm					
Average 85 Acres $8,866 7.97 months					
With Buildings	1.15895	.13529	25	1.17492	Reject H_o
Without Buildings	1.15403	.061264	26	2.51425	Reject H_o

differences between the two groups. In the large farms group (without buildings), the sum of the elasticity coefficients is a little smaller than unity indicating a slight tendency to diminishing returns to scale. However, in the small farm group, the sum of the regression coefficients is larger than unity, suggesting increasing returns to scale. Increasing all factors by one percent will be associated with an increase in gross income of 0.98 percent in the large farms group and 1.15 percent in the small farms group.

A test of significance indicated that, at a five percent probability level. The results do not differ significantly from linear for the large farms group. However, the results differ significantly from constant returns for the small farms group.

Judging from the sums of coefficients of factor inputs and the results of significance test, constant returns to scale seem to prevail at the farm firm level for large farms and increasing returns to scale prevail for small farms in the region studied. This can be explained partially by the fact that small farms have a high degree of part-time farming and consequently rely more on nonfarm income. More often than not, these farmers cultivate their land in their spare time from off-farm occupations. Labor and machinery would not be used efficiently on the smaller farms under this condition due to acreage limitations and time constraint imposed on labor. With increased amounts of labor, land, machinery investment and operating capital, the greater volume could permit farmers to devote more time to farming and do a better job of using their resources.

The estimated gross income for all farms, at the geometric mean, was computed by inserting a constant term (log A = 1.32195), the estimated b_i's and the logs of the geometric means of the input categories in the prediction equation. It was found that log $\hat{Y}$ = 4.16883 (or $\hat{Y}$ = \$14,751) with a standard error of estimate ($\hat{S}$) of 0.11950, i.e., under the production conditions prevailing in 1972, log $\hat{Y}$ would be expected to fall between 4.16883 $\pm$ 0.11950 for typical farm organization in 68.27 percent of the sample, or in natural numbers between \$11,203.00 and \$19,424.00.

The marginal value products of land, labor, operating expenses and machinery investment for typical farm organization were computed as in Table 5.7.

A comparison between the estimated regression coefficients and the coefficients necessary to yield minimum expected returns is shown in Table 5.8.

The estimated coefficients were lower than the coefficients required to yield minimum return for operating expenses, machinery investment and labor when considering

Table 5.7. Estimated Marginal Value Products of Typical Organization Farms (Based on 61 Cash-Grain Farms in Clinton and Ionia Counties)

Input Category	Quantity of Input (Geometric Mean)	Regression Coefficient	Marginal Value Product (Dollars)
X_1 Land	142.08 Acres	.51541	53.51
X_2 Labor	7.36 Months	.26672	534.60
X_3 Operating Expenses	\$5,265	.23763	.67
X_4 Machinery Investment	\$16,886	.14711	.13

entrepreneur's return as a minimum return. The differences are large enough to fall beyond the 68 percent confidence interval for operating expenses and machinery investment, and the 95 percent confidence interval for entrepreneurial labor valued at \$833 per month.

On the other hand, the estimated coefficients were higher than the coefficients required to yield minimum return for land, operator and family labor. The differences, however, were small enough to fall within the 68.27 percent confidence intervals for better land ($MFC_{X_1} = \$50$) and operator labor ($MFC_{X_2} = \$500$).

The estimated coefficient for labor was lower than the coefficient required to yield a return of \$833 for entrepreneurial labor that the coefficient falling beyond the 95 percent confidence intervals.

Table 5.8. Comparison of Estimated b_i's and b_i's Necessary to Yield Minimum Marginal Value Products

Variable	Estimated b_i	Standard Error of Estimated b_i	b_i to Yield Minimum Return	Difference
Land, Acre X_1	0.51541210	0.08894869	0.3949074 (MFC_{X_1} = \$41)	0.1205047
			0.4815944 (MFC_{X_1} = \$50)	0.0308177
Labor, Month X_2	0.26672362	0.06605426	0.1995796 (MFC_{X_2} = \$400)	0.06714402
			0.2494746 (MFC_{X_2} = \$500)	0.01724902
			0.4156247 (MFC_{X_2} = \$833)	-0.14890108
Operating Expenses Dollar, X_3	0.23763110	0.11501469	0.3712019 (MFC_{X_3} = 1.04)	-0.1335708
Machinery Investment Dollar, X_4	0.14710564	0.07993501	0.2861839 (MFC_{X_4} = .25)	-0.13907826

The Third Equation, Assuming Constant Returns to Scale

From the previous discussion, we have noticed that the sums of elasticity coefficients for the large and small farms reveal distinct differences between these two sizes. The sums of the regression coefficients are 0.98 and 1.15 for large and small farms, respectively. The former indicates a slight tendency to diminishing returns to scale, while the latter suggests increasing returns to scale.

As estimated returns to scale for the large farms were not significantly different from one the data for all farms were fitted to a Cobb-Douglas production function imposing the restriction of constant returns to scale. The resulting estimated regression coefficients, together with relevant statistics, are presented in Table 5.9.

The standard error of the regression coefficients was comparatively small for the constant term and land, resulting in a considerably large value of T-statistics. The results of the t-test indicate that the estimated coefficients were different from zero at levels of significance of .05 percent for land, 5 percent for labor, one percent for operating expenditures and were not significantly different from zero at the 5 percent level of significance for machinery investment.

Table 5.9. Regression Coefficients and Related Statistics of the Estimated Production Function (61 Farms) with Σb_i Forced Equal to 1.

Variables	Regression Coefficients (b_i)	Standard Error of Coefficients	T-Statistics for Testing H: $b_i = 0$
Constant Terms	1.56313	.26180	5.9706
Land, Acre, X_1	.45118	.09296	4.8537
Labor, Month X_2	.15446	.05954	2.5944
Operating Expenses, Dollar, X_3	.32905	.11948	2.7541
Machinery Investment, Dollar, X_4	.06531	.08113	.8050

Multiple correlation coefficient, R = .9513

Coefficient of determination, R^2 = .9051

Forced sum of regression coefficient, 1.00000

The multiple correlation coefficient (R) is .9513, indicating that the correlation between gross income and all factor inputs specified in the model is quite high. The coefficient of determination (R^2) is .9051, suggesting that 90.51 percent of the variation in the logarithm of the estimated gross income was explained by the independent variables included in the analysis.

The standard error of estimate ($\hat{S}$) of the dependent variable (log Y) was .12836. This indicates that under production and price conditions prevailing in 1972, the logarithm of actual gross income would be expected to fall between 4.16881 $\pm$ .12836 in 68.27 percent of the sample, or in natural numbers between $10,976 and $19,823.

The marginal value products of each factor input for typical organization were computed as in Table 5.10.

Table 5.10. Estimated Marginal Value Products of Typical Organization Farms (Based on 61 Cash-Grain Farms in Clinton and Ionia Counties)

Input Category	Quantity of Input (Geometric Mean)	Regression Coefficient	Marginal Value Product (Dollars)
Land, X_1	142.08 Acres	.45118	46.84
Labor, X_2	7.36 Months	.15466	309.57
Operating Expenses, X_3	$5,265	.32905	.92
Machinery Investment, X_4	$16,886	.06531	.06

The estimated regression coefficients were compared with the coefficients necessary to yield minimum expected return. The results of the comparison are shown in Table 5.11.

Table 5.11. Comparison of the Estimated b_i's and the b_i's Necessary to Yield Minimum Marginal Value Products

Variable	Estimated b_i	Standard Error of Estimated b_i	b_i to Yield Minimum Return	Difference
Land, Acre X_1	.45118	.09296	.39491 (MFC_{X_1} = \$41)	.05627
			.48159 (MFC_{X_1} = \$50	-.03041
Labor, Month X_2	.15446	.05954	.19958 (MFC_{X_2} = \$400)	-.04512
			.24947 (MFC_{X_2} = \$500)	-.09501
			.41562 (MFC_{X_2} = \$833)	-.26116
Operating Expenses, Dollar, X_3	.32905	.11948	.37120 (MFC_{X_3} = \$1.04)	-.04215
Machinery Investment, Dollar, X_4	.06531	.08113	.28618 (MFC_{X_4} = \$.25)	-.22087

The estimated regression coefficients were lower than the coefficients required to yield minimum return for all input categories except land at the low price (MFC_{X_1} = \$41). The differences are large enough to fall beyond the 68.27 percent confidence interval for operator labor, 95 percent confidence interval for machinery investment and 99 percent confidence interval for entrepreneur (MFC_{X_2} = \$833).

The difference, however, is small enough to fall within 68.27 percent confidence intervals for land at the high price, family labor (MFC_{X_2} = \$400) and operating expenses (MFC_{X_3} = \$1.04).

On the other hand, the estimated coefficient was higher than the coefficient required to yield minimum return for land at the low price, but the difference is small enough to fall within the 68.27 percent confidence interval.

It is worth noting that the estimated coefficient for labor was lower than the coefficient required to yield a return on entrepreneurial labor of \$835 a month, that coefficient falling beyond the 99 percent confidence intervals. This suggests that the return in the agricultural sector in 1972 was not high enough to provide an incentive to most potential entrepreneurs from the nonagricultural sector to enter cash cropping in central Michigan.

Land yielded fairly good returns in the typical farm organization as shown in Table 5.10. On such a farm, the estimated marginal earning of tillable land was estimated to be around \$47 per acre, so that an increase of one acre in crop area would result in a \$47 increase in gross income. However, in view of the fairly high correlation existing between land and operating expenses and between land and machinery investment, it appears that the regression coefficient for land is overestimated with compensating underestimation of the coefficients for cash expenses and machinery. Thus the estimated marginal value products of machinery investments and productive cash expenses are regarded as low while the estimated marginal value product of tillable acres of land as high. In the writer's judgment, estimated marginal earning of tillable acres of land was actually between $37 and $45 per acre. The comparatively high return to land indicates the desirability of a moderate expansion in acreage, at least within the constraints imposed by available labor and equipment.

The amount of labor used on the "typical" farm was found to be 7.36 man-months per year with an estimated marginal value product of about $310 per month. This implies that gross income would have increased about $310 a month had additional labor been used beyond the 7.36 months used. Labor earnings can be increased by additional investment in land and other inputs or by using less labor relative to other inputs.

Operating expenditures amounted to $5,265 on the usual or typical farm studied. Since cash expenses are used up in a year's operation, they should be expected to return at least a dollar for the last dollar spent, plus interest on the money from the time it was spent until recovered. The estimates indicate that the last additional dollar expended for this input category returned only 92 cents to the farms. However, operating expenses were used in amounts rather closely related to the land inputs and the chances of error in the estimate are increased due to this close relationship. There appears to be some reason for suspecting that part of the return to operationg expenses is reflected in the estimated marginal value product of land inputs. Therefore, it is concluded that the marginal value product of operating expenses was slightly over a dollar ($1.01) for a dollar spent in 1972.

The estimates indicate that machinery on the typical farm was earning low returns. However, the high correlation between land and machinery may have caused the estimated marginal value product of land to be high and the estimated marginal value product of machinery to be low. It is the belief of the author that the marginal earning of machinery was between 12 and 21 cents per dollar per year. This return hardly covers depreciation, interest, insurance, and maintenance which usually amount to about 25 cents per dollar investment. The low return to machinery reflects a large machinery investment of $16,886 which might profitably be reduced both relatively and absolutely. Therefore, further investment in machinery seems unlikely to be profitable unless land and other supporting inputs are substantially increased.

It should be remembered that the estimates of marginal value productivity are based on 1972 prices and weather conditions. In order to update the estimates, these value productivity estimates were adjusted for changes in product and factor prices in 1973.

The separate marginal value productivities of investments and inputs for the typical farm at 1973 prices together with the 1972 MVP's at the "usual" farm organization are shown in Table 5.12.

Table 5.12. Adjusted Estimates of Marginal Value Products of Typical Organization Farms in 1972 and 1973 (Based on 61 Cash-Grain Farms in Clinton and Ionia Counties)

Input or Investment	Usual Amount (At 1973 Prices)	Marginal Value Product (1972 Prices)	Marginal Value Product (1973[1] Prices)
Land, X_1	142.08 acres	\$37 to \$45 per acre	\$66 to \$80 per acre
Labor, X_2	7.36 months	\$310/month	\$554/month
Operating Expenses, X_3	\$6,002	\$1.01/dollar	\$1.58/dollar
Machinery Investment, X_4	\$18,237	12 to 21 percent	20 to 35 percent

[1]1973 price indexes used in this computation are: 178.65 for farm products, 108 for machinery investment and 114 for operating expenditure, where 1972 = 100.

Source: Computed from Agricultural Prices, USDA, 1972, 1973.

The adjustment technique used in this study is based on the following formula:[7]

$$MVP_{X_{i(t=n)}Y_{t=n}} = \frac{b_i E(Y)_{t=0}}{X_{i(t=o)}} \cdot \frac{I_{Yt=n}}{I_{X_{i(t=n)}}}$$

Where:

$I_{Yt=n}$ = price index of farm products at n year;

$I_{X_{i(t=n)}}$ = price index of inputs at n year;

$E(Y)$ = $AX_1^{b_1} \ldots . X_i^{b_i} \ldots \ldots X_n^{b_n}$;

$X_{i(t=o)}$ = geometric mean input of X_i at the base period (i = 1,. . .,n);

b_i = regression coefficients of X_i (i = 1,. . .,n).

At 1973 prices, the return to land indicates the desirability of an expansion in acreage. Use of more land would maintain the earnings of larger amounts of labor and operating expenditures. Larger land investments would also increase the earning power of machinery investments. The return to machinery investments, even at 1973 prices, is low compared to depreciation, interest, repair and tax costs, which amount to at least 25 percent.

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[7]Trant, G. I., "Adjusting for Price Levels in Production Function Studies," reprinted in Resource Productivity, Returns to Scale, and Farm Size. Edited by E. O. Heady, G. L. Johnson and L. S. Hardin, The Iowa State College Press, Ames, Iowa, 1956, p. 164.

Thus, even at 1973 prices, machinery investments should not be increased unless supporting inputs and investments (particularly land) are increased substantially. The earning power of farm labor was probably still not high enough to compete with industrial wage rates even at 1973 farm product prices; hence, few farms could consider expanding their use of really reliable, high-paid, skilled labor.

The MVP of the Usual Combinations of Land, Labor, Operating Expenditure, and Machinery

Since the amounts of land, machinery investment and other expenses used tended to change together from farm to farm, it is worthwhile to estimate the combined marginal value productivity of these inputs and investments. The study shows that these four inputs and investments yielded low returns when considered jointly.

With a usual "batch" of inputs used, an additional acre of land, combined with 1/20 months of labor, $37 operating expenses and $119 machinery investment, would add about $104[8] to gross income. The corresponding additional cost of using these additional inputs and investments in 1972 was around $119 (i.e., $30 for rent/acre; $20 for 1/20 months labor; $39 for $37 operating expenses and $30 for a $119 machinery investment). Apparently, the typical farmer would incur losses by using an additional $119 inputs. It should be noted that all these estimates apply to 1972 prices and production conditions.

[8] This figure is computed from Table 5.10.

What would the combined marginal value productivity of these four inputs and investments be under 1973 price conditions? To answer this question, the farm product price index for 1973[9] was computed using 1972 as a base year. The index was found to be 178.65, indicating farm product prices were increased by 78.7 percent compared to 1972 prices.

Also in 1973, corresponding costs of the additional resources increased to $141 (i.e. $40 for rent/acre; $25 for 1/20 months labor; $40 for $37 operating expenses and $36 for a $119 machinery investment). Thus, at 1973 prices, a farmer could obtain $193 additional gross income of $52 additional net income using an additional $141 more inputs. For the typical farm, gross income would have increased from $14,751 in 1972 to $26,353 in 1973, an increase of $11,602. This indicates quite favorable conditions for farmers in 1973.

Reorganization and Development of Farms on the Basis of Estimates

One of the objectives of this study was to provide an objective and reliable basis for evaluating current

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[9] The prices used in computing the price index of 1973 were as follows: prices per bushel: $2.25 for corn; $5.50 soybean; $4.25 wheat; $1.25 oats; $15 per cwt. for dry beans and $40 per ton for hay.

farm organization and to serve as a guide for reorganizing farm business.

Judging from the considerably high correlation existing between land and productive cash expenses and between land and machinery investment, some estimated coefficients were believed not reliable enough for use in estimating gross farm income and marginal value products for different combinations of factor inputs. Therefore, an effort was made to adjust the estimated coefficients in a rough "Bayesian" way. The adjustments were based on information and data obtained from nonsurvey sources and according to the author's judgment. The adjustments are summarized in Table 5.12. The adjusted regression coefficients and the consequent marginal value products of each factor inputs for a typical farm were presented in Table 5.13.

Table 5.13. Adjusted Estimated Regression Coefficients and Marginal Value Products of Typical Organization Farms in 1972 (Based on 61 Cash-Grain Farms in Clinton and Ionia Counties)

Input or Variable	Quantity of Input (Geo-Metric Mean)	Nonadjusted Regression Coefficient	Adjusted Regression Coefficient	Adjusted Marginal Value Product (1972)
Constant Terms		1.56313	1.37096	
Land, X_1	142.08 acres	.45118	.3550	$37/acre
Labor, X_2	7.36 months	.15446	.1520	$305/month
Operating Expenses, X_3	$5,265	.32905	.3600	$1.01/dollar
Machinery Investment, X_4	$16,886	.06531	.1330	12 percent

In this section, the reorganization of farms was based on the adjusted regression coefficients and on the assumption that constant returns to scale (i.e. $\sum_{i=1}^{4} b_i = 1$) prevail in the region studied.[10]

The first case to be considered is to examine the effect of increasing an input (land) having a higher rate of return on gross income and marginal value products. The effects of increasing land area from 142 acres to 250 acres while using typical quantities of the other input categories are shown in Table 5.14.

Table 5.14. Changes in MVP and Gross Income Resulting From Increasing Land Area From 142 Acres to 250 Acres

Input Category	Quantity of Inputs	Original MVP and Gross Income ($)	New MVP and Gross Income ($)
Land, X_1	250 acres	37	26
Labor, X_2	7.36 months	305	372
Operating Expenses, X_3	$5,265	1.01	1.23
Machinery Investment, X_4	$16,886	.12	.14
Estimated Gross Income		$14,751	$18,027

[10]Under the assumption of constant returns to scale, the optimum size of a farm does not exist. However, once one or more factors were fixed, their subfunctions would be subjected to diminishing returns and thus an optimum farm size could be determined.

All marginal value products were increased by the expansion of tillable acres except the marginal value product of land, which decreased from $37 to $26. Estimated gross income increased from $14,751 to $18,027. The increase in gross income was due not only to increased revenue from the expanded land area, but also to increased marginal productivities of other factor inputs when used in combination with more of the input (land) earning a higher rate of return. This phenomenon illustrates the twofold effect of the law of diminishing returns.

The effect of increasing tillable acres on labor productivities is shown in Figure 1 and in Table 5.15.

Table 5.15. Marginal Value Products of Labor at a Different Level of Tillable Acreage

Labor (Month)	Acreage			
	142	200	250	300
	----------Dollar----------			
7	318	359	389	415
10	235	265	287	306
13	188	212	230	245
16	158	178	193	206
19	136	154	167	178
22	120	136	147	157
25	108	122	132	141

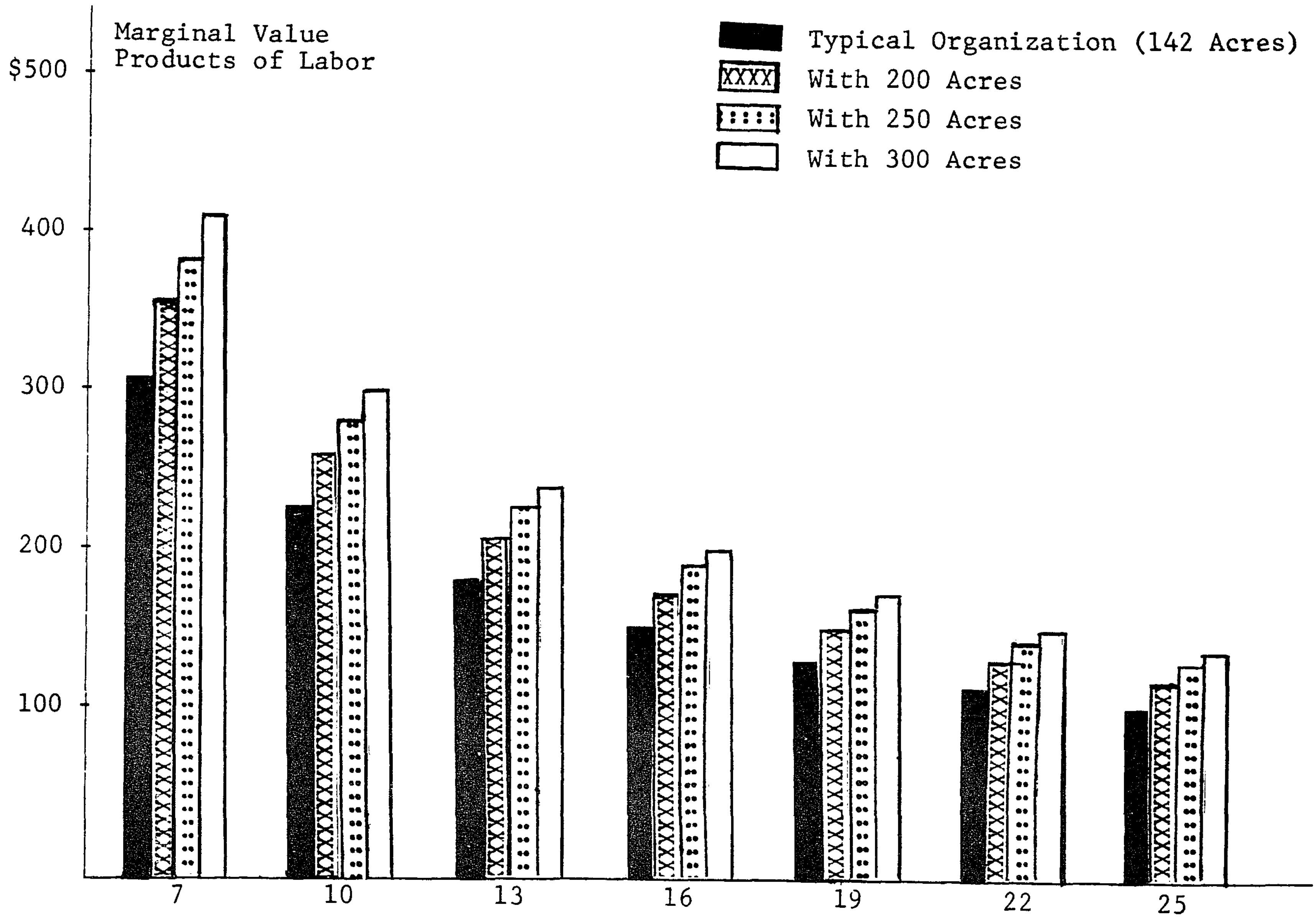

Figure 5.1. Effects of different level of acreage on marginal value productivity of labor

It is apparent that when the amount of labor employed increases, the marginal value product of labor decreases rather rapidly at first, then less rapidly as months of labor are increased. It is also noticed that the marginal value product of labor shifts upward when tillable acreage is increased. The amount of the shift decreases as more land is used. This is again due to the effect of the operation of the law of diminiishing returns.

For the purpose of explaining how the estimates may be used in finding more profitable input combination, an alternative organization, along with the resultant estimated marginal value product and gross income, is shown in Table 5.16.

Table 5.16. An Alternative Organization of Typical Farms Studied in Clinton and Ionia Counties, 1972

Input Category	Quantity of Inputs (X_i)	Log X_i	Regression Coefficient (b_i)	(Log X_i) $\cdot$(b_i)	MVP (Dollars)
Land, X_1	350	2.54407	.3550	.90314	24.09
Labor, X_2	8	.90309	.1520	.13727	451.21
Operating Expenses, X_3	8,000	3.90309	.3600	1.40511	1.07
Machinery Investment, X_4	16,000	4.20412	.1330	.55915	.20

Log Constant (A) = 1.37096

Σ Log $X_i \cdot b_i$ + Log Constant (A) = 4.37563

Log^{-1} 4.37563 = \$23,748 = Estimated Gross Income

The input category given most emphasis in developing this particular organization from the original one was the land category, since it was generating higher returns.

As the amount of land was increased, its estimated marginal value product decreased from $37 to $24. Although amounts of machinery investment and labor were not significantly changed in this organization, their estimated marginal value products increased from $.12 to $.20 per dollar and from $306 to $451 per month, respectively. This is a result of using relatively more supporting inputs, i.e. land and operating expenses.

Gross income for the typical organization increased from $14,751 to $23,748 resulting in a net increase in gross income of $8,997 under production and marketing conditions prevailing in 1972.

To illustrate a further application of the results of this study, a large farm in the sample was selected and an alternative organization constructed.

The quantitites of inputs used on this farm with their estimated marginal value products are shown in Table 5.17.

Examination of the estimated marginal value products shows that marginal return to labor for this particular farm was substantially higher than the average ($309.57) with lower than average return ($1.01) to operating expenses. The high earning power of labor on the farm suggests the

Table 5.17. Estimated Marginal Value Products--Existing Organization and an Alternative Organization for a Farm Studied in Clinton and Ionia Counties, 1972

Input Category	Existing Organization		Alternative Organization	
	Quantity	MVP ($)	Quantity	MVP ($)
Land, X_1	1,386 acres	28.44	1,500 acres	27.16
Labor, X_2	27.85 months	606.04	40 months	436.05
Operating Expenses, X_3	$45,980	.87	$40,000	1.03
Machinery Investment, X_4	$93,375	.158	$93,375	.163
Gross Income	$111,040		$114,750	

desirability of an expansion in the use of labor. On the other hand, the low return to operating expenses reflected a large amount of cash expenses which might profitably be reduced. Accordingly, an alternative organization was developed.

Labor was increased while operating expenses were reduced. Land was moderately increased while machinery investments remained unchanged. As a result, the marginal returns to land and labor decreased and the earning power of cash expenses and machinery increased. This illustrates the twofold effect of the operation of the law of diminishing returns. The expected gross income increased from $111,040 to $114,750, resulting in net increase in gross income of $3,710.

The estimates show the relationship between each category of input and gross income derived from the 61 sample cash-grain farms in Clinton and Ionia counties during 1972. The results of the study provide a basis of estimating returns that might have been realized under the same conditions had different farm organization been adopted. However, it is worth noting that the future return depends much on future prices of inputs and outputs.

It is believed that the typical organization in this study was not too far from optimal organization. However, some adjustment is considered necessary in order to raise farm income. The main adjustments seem to be: (1) to moderately increase farm size by expanding tillable acreage, (2) to reduce the use of labor, and (3) to be more careful in handling current operating expenditures and machinery investments.[11]

Summary and Implications

The purpose of this chapter was to estimate marginal value productivities for various inputs and investments in cash grain farm business of south central Michigan.

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[11]The model does not consider off-farm work as a way of using farm operator labor.

Functional analysis was employed in this chapter because of its capability to measure the effects of interaction of different levels of inputs and investments on their respective value productivities. The data obtained from the 61 sample farms were used as a basis for three regression analyses.

The first equation includes five variable input categories, i.e. land, labor, operating expenses, machinery investment and buildings.

In the second equation, buildings were omitted to obtain a better fit with greater confidence in the estimates of the production coefficients.

In the third equation, constant return to scale was assumed.

A tentative conclusion from examining the typical organization of cash-grain farms on Miami or better soils in the two counties in 1972 was that marginal value product for land was comparatively high, indicating the desirability of a moderate expansion in farm acreage. Since much cropland was either diverted by government set-aside programs or simply idle in 1972, an increase in crop area by expanding the extensive margin of cultivation was indicated for 1972 and 1973 conditions.

Operating expenditures and machinery investments were high compared to other inputs, as reflected by the low returns of these input categories. This implies that more care in handling operating expenses and machinery investment is desired, and expanded farm sizes are needed in order to use machinery and operating expenditures more effectively. Some ways of reducing machinery investment have been noted, but much improvement in this direction cannot be assured because of indivisibility of machinery.

Farm labor studied was earning a low rate of return in 1972. The estimated marginal value product of labor was found to be $309.57 per month, indicating that an increase of one month's work on the farm would be accompanied by an increase of $309.57 in gross income, holding other factor inputs constant at their respective geometric mean levels. This implies that most cash-grain farms in the area studied are not able to compete with industry for hired labor. The low earning power of labor also indicated the desirability of reducing its use relative to land and other inputs.

An increase in land use would tend to reduce its marginal earning power, but at the same time would increase marginal earnings of machinery, operating expenditures and labor. Consequently, farm income would be higher due to a better farm resource combination involving more land relative to machinery and, especially, labor.

The results of the study provide a basis of estimating returns that might have been realized under the same conditions but with different farm organizations. However, future returns depend on future conditions of prices, technology, institutions, weather conditions, and human factors. In applying the results of this study, these factors together with the limitations of the study previously mentioned must be taken into account.

CHAPTER VI

PROJECTED CONSEQUENCES OF ALTERNATIVE WAYS OF ORGANIZING THE USE OF MIAMI/CONOVER SOILS IN SOUTH CENTRAL MICHIGAN

In this study, static linear programming has been employed to investigate the profit-maximizing organizations and land use for representative farms in the select area. In addition, a Cobb-Douglas analysis has been used to estimate the marginal value productivity of the resour on the selected farms.

The purpose of this chapter is to relate the results of the study to the micro, as well as macro aspects of decisions regarding land use programs and policies which could lead to more efficient and wise use of land resources In the first place, an evaluation will be made of the resu of linear programming, in light of the results of functior analysis. Secondly, the general land use situation and th factors affecting the utilization of land will be describe Thirdly, land policy implications based on the study will be presented. Lastly, the projected consequences of alter native ways of organizing the use of Miami/Conover soils will be presented.

Evaluation on the Results of the Linear Programming and Cobb-Douglas Function Analyses

The results of linear programming have to be examined in light of the results drawn from the functional analysis. Both locate optima but different optima and in different ways.

In linear programming, a priori information about productivity coefficients is required before the actual process is undertaken. Thus, the resultant productivity estimates (i.e., shadow price of a resource) are dependent on coefficients of productivity obtained independently of the program.

The results of the functional analysis indicated (1) fairly high returns to land, (2) low returns to farm labor, (3) low returns to cash operating expenditures, and (4) low returns to machinery. Near constant returns to scale beyond 150 tillable acres were found empirically in the functional analysis but were assumed in the linear program. The findings of the functional analysis confirm the assumptions of the linear programming analysis. Both functional and programming analyses indicated high returns to land and low returns to other inputs and investments.

The functional analysis indicates the desirability of a moderate expansion in farm size to more fully utilize family and operator labor and machinery due to comparatively high returns to land. The programming results indicate the profitability of expanding farm size by renting and/or through purchasing land up to the limit permitted by the model (Table 4.4). In the linear programming analysis some additional unskilled labor is required, seasonally, in conjunction with the expansion in land use.

The programmed results are based on several assumptions which require evaluation before accepting these conclusions.

The land price of $500 per acre and annual rental rate of $30 per acre assumed in the model are considered low. As such, the consequent programming result is the expansion of farm size for all representative farms by renting and/or through purchasing land up to the limit permitted by the model (Table 4.4). Land often becomes the most limiting resources as reflected by its high shadow price. When more land is available for rental, the linear programming analysis concentrates on expansion of land through renting probably because rent at $30 an acre is low priced relative to the purchase price of $500 per acre (Table 4.8, Case V).

The optimum solutions are affected by the assumptions made relative to available off-farm employment. The model assumed that off-farm opportunities were limited in five seasons. A perfectly elastic supply schedule for labor hired was assumed. These assumptions are probably invalid as wage rates are increasing and young rural people increasingly work off farms. Moreover, the agricultural sector is increasingly affected by the increase in the price of purchased farm inputs caused by the energy crisis which were not considered in the programming model. Product prices used in the programming analysis are much higher than the product prices used in the functional analysis.[1] Assumptions concerning the credit supplies in the programming analysis are based on the usual practices of institutional lenders. No provisions were made in the model for internal credit rationing due to uncertainty.

The linear programming model does not consider the overall aggregate effects of large scale adoption of the results on product and input markets. The programmed solutions call for expansion of farm size and associated durable assets to produce specific crops. However, if all farmers bid for resources, land and associated input prices would increase while product prices would likely decrease. This trend would limit expansion of farm size.

Lastly, risk and uncertainty in production was not considered in the model. Lack of knowledge about future technology, institution, people and prices often cause a farmer to act more conservatively.

The qualifications presented above indicate that farm size would actually be smaller than that indicated in the

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[1]The prices used to compute the value of farm products in functional analysis were the average price of each crop in Michigan in 1972. These prices per bushel were: $1.12 for corn; $3.27 soybeans; $1.62 wheat; $0.76 oats; $10.53 per cwt. for field beans. In contrast, the prices used in linear programming were 1973 fall prices except field bean price. These prices per bushel were: $2.25 for corn; $5.50 soybean; $4.25 wheat; $1.25 oats; $15.00 per cwt. for field beans (i.e., normal price of field beans).

programmed solution. The lower marginal value product of land found in the functional analysis and nonexistence of increasing return to scale beyond 150 tillable acres also support the above statement. Judging from the existence of considerable amounts of unused cropland and potential cropland and the fairly high returns to land as shown by both the functional and programming analyses, it is concluded that the trend toward a moderate increase in farm size should be expected to continue in a foreseeable future. The continued development of larger and efficient machinery and rapid adoption of larger machines would probably give additional momentum to this trend.

The desirability to expand farm size as shown by both the programmed solutions and functional analysis implies that land values in the area will continue to be bid up as farmers seek more land for farming, along with the increase in demand for land for other uses. This trend would probably discourage the establishment of new farms as more capital would be required for the land resources, combined with high labor cost, expensive machineries and high land clearance cost.

As farm size becomes larger coupled with high labor costs, larger and more efficient machines and equipment are needed in order to complete field work in time. This implies that more capital is required to replace expensive labor. On the other hand, the majority of young rural people tend to leave farming as more attractive off-farm work is available for them. As old farmers retire, the total work force in agriculture is reduced while total farm land remains relatively stable or slightly increases. Farms with limited labor but with larger acreages could probably generate higher farm income. However, it takes quite a long time to make this kind of adjustment.

Land Use on Miami/Conover Soils

This section presents the results of the land utilization survey on Miami/Conover soils in Clinton and Ionia counties for the operating year 1972. The purpose of this part of the survey was to examine the overall land utilization and quantity idled on the Miami or better soils, and reasons for such land being idle. As such, the approach is descriptive with emphasis on acreages of land used for various purposes, rather than on theoretical matters.

The year 1972 is selected because it was the year before agricultural product prices increased significantly.

As part of the survey, data were collected from farmers concerning their 1972 land utilization using "land utilization schedule" and aerial photographs for the selected areas.

As previously stated, a random sample of twenty predominantly Miami/Conover areas (two mile square area, containing four square miles) was drawn for this study. All farmers whose farmsteads fell in selected areas were questioned as to the kinds and acreage of crops planted in each tract on their farms in 1972. An effort was made to distinguish between diverted cropland and idle cropland. The former is land idled by government production control programs while the latter is a land idled by a farmer for some other reasons.

The results of land use survey for each area in the two counties are presented in Table 6.1 (actual acreage) and Table 6.2 (percentage).

As shown in Table 6.1, most of Miami/Conover soils (68 percent) were used for crop production including corn (15,888 acres), legume-grass hay (5,369 acres), wheat (5,279 acres), soybeans 3,572 acres), field beans (3,057 acres), oats (1,391 acres) and other crops (371 acres). Also, fairly large areas were in woodland which accounts for 7.91 percent (4,049 acres), while pasture constituted 3.82 percent (1,956 acres) of the total area.

Quite a few acres of cropland (4,863 acres, or 9.5 percent) were diverted by government set-aside programs, or simply idled (784 acres or 1.53 percent) by the farmer. Much of the idle cropland comprises 11.03 percent (5,647 acres) of total area investigated. The diverted cropland (4,863 acres or 9.5 percent) has probably been pulled into production since 1972 as all farmers interviewed indicated that they would like to increase crop production by bringing diverted cropland back into production after the termination

Table 6.1. Use of Land in Clinton and Ionia Counties in 1972 (Miami/Conover Soils)--by Acreage

Area	Total	Corn	Soybean	Wheat	Field Beans	Oats	Hay	Other Crops	Pasture	Woodland	Swamp	Diverted Land	Idle Land	Others[1]
1	5,120	1,792.90	160.70	334.10	---	303.40	987.00	6.10	314.10	338.60	15.00	527.70	21.00	319.40
2	5,120	1,646.50	482.00	501.90	176.90	160.50	768.60	12.20	238.90	393.30	16.00	345.20	4.00	374.00
3	5,120	1,350.50	487.90	477.10	340.50	92.60	635.40	5.10	218.30	473.60	55.50	384.80	92.70	506.00
4	5,120	1,604.50	471.70	361.30	190.9	192.80	707.50	---	285.30	278.00	38.00	578.80	67.30	343.90
5	5,120	1,166.10	480.50	768.00	528.10	49.00	396.10	123.00	127.70	402.30	15.00	500.10	55.30	510.80
6	5,120	1,443.60	257.50	446.60	676.15	121.50	443.90	29.20	209.20	397.80	---	536.80	146.60	411.15
7	5,120	1,669.60	267.60	668.00	479.90	210.80	298.40	31.50	168.70	288.30	---	528.41	59.90	446.99
8	5,120	1,790.14	447.70	424.30	258.80	26.40	365.50	78.80	91.10	428.00	---	534.00	160.30	494.96
9	5,120	1,773.60	293.30	541.40	221.90	58.00	357.40	17.30	192.90	562.10	20.00	460.30	97.30	544.40
10	5,120	1,650.60	222.80	756.00	183.80	176.00	409.30	67.50	109.40	486.50	108.80	467.10	79.30	402.90
Total	51,200	15,888.04	3,571.70	5,278.70	3,056.95	1,391.00	5,369.10	370.70	1,955.60	4,048.50	268.30	4,863.21	783.70	4,354.50

[1]Others include land used for roads, building lot and ditches, etc.

Table 6.2. Use of Land in Clinton and Ionia Counties in 1972 (Miami/Conover Soils)[1]--by Percentage

Area	Cropland	Pasture	Woodland	Swamp	Diverted Cropland	Idle Cropland	Others	Total
1	70.01	6.13	6.61	.29	10.31	.41	6.24	100
2	73.22	4.67	7.68	.31	6.74	.08	7.30	100
3	66.20	4.26	9.25	1.08	7.52	1.81	9.88	100
4	68.93	5.57	5.43	.74	11.30	1.31	6.72	100
5	68.53	2.49	7.86	.29	9.77	1.08	9.98	100
6	66.77	4.09	7.77	---	10.48	2.86	8.03	100
7	70.82	3.29	5.63	---	10.32	1.17	8.77	100
8	66.63	1.78	8.36	---	10.43	3.13	9.67	100
9	63.34	3.77	10.98	.39	8.99	1.90	10.63	100
10	67.69	2.14	9.50	2.13	9.12	1.55	7.87	100
Total	68.21	3.82	7.91	.52	9.50	1.53	8.51	100

[1]Computed from Table 6.1.

of government production control programs. The estimated crop acreage which could be pulled into production averaged approximately 31 acres per farm. The cost of bringing diverted cropland into cultivation was small enough to be negligible.

Whether or not the other idle cropland (1.53 percent) could be pulled into production is unknown due to many factors involved in the use of such land. This point will be discussed in the next section.

Pasture land (3.82 percent) and woodland (7.91 percent) could be pulled into production if there is sufficient economic justification. The cost of bringing unused land into production bears on the feasibility of cultivating land now unused. The estimated cost of clearing plowable pasture is approximately \$80 per acre while clearing woodland costs about \$500 per acre at 1973 prices. Plowable pasture would likely be converted into cropland, if other land is not available for renting at \$30 per acre or for purchase at \$500 per acre and product prices remain high. However, programmed results show that no woodland would be cleared at the cost of \$500 per acre (Table 4.8).

Consequently, it is reasonable to assume that sources of potential acreage expansion come mainly from diverted cropland (9.5 percent) and plowable pasture (3.82 percent). Using these figures, the potential crop acreage expansion in Miami or better soil could be estimated. To do this, however, requires an estimate of the acreage of Miami/ Conover soils in the studied area.

The total area of Miami/Conover soils in the two counties is estimated to be approximately 252,802 acres.[2] Therefore, the estimated diverted cropland was 24,016 acres (i.e., 252,802 x .095) while plowable pasture is about 9,657 acres (i.e., 252,802 x .0382). In total and as of 1972, approximately 33,673 acres of cropland not farmed in 1972 in Miami/Conover soils in the two counties could be pulled into production at 1973 price relationships. It should be noted that pulling 33,673 acres of cropland into production could easily be accomplished by expanding the size of existing farms. However, it is difficult, if not impossible, to bring the land into production through establishing new farms due to its scattered location and the lack of monetary incentives for new entrepreneurs. It is worth mentioning that farm size could continue to increase under the condition of constant returns to scale. The process could be accomplished through the consolidation of the existing small farms with low farm earnings and/or by buying out old farms which can not make adjustments for economic survival.

In the following section, the factors affecting land utilization will be discussed.

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[2]Computed from: (1) Soil Survey-Clinton County, Michigan, USDA and Michigan Agricultural Experimental Station, Series 1936, No. 12, p. 14; (2) Soil Survey-Ionia County, Michigan, USDA and Michigan Agricultural Experiment Station, December 1967, pp. 6-8.

Major Factors Affecting Utilization of Land

There are quite a few factors which would affect the utilization of land. In general, these factors can be classified into four categories: (1) physical factors including such factors as water supplies, soil types, terrain, geography and climate, (2) technological factors including new varieties, irrigation, drainage, tiling, fertilizers and improved technology, (3) economic factors which are based primarily on economic principles (i.e., productivity or profit) that affect the use of land resources, and (4) institutional factors including legislation with regard to property rights, land tax, leasing arrangements, planning, zoning, education and safety, etc.

It should be noted that no single factor could establish the pattern of land use for a given land area. Rather, combinations of many factors determine the specific use of land. It should also be recognized that it would be extremely difficult to determine the extent to which each factor influenced the intensity and efficient use of land. In other words, the determination of relative effects of those factors on land utilization is very difficult, if not impossible.

This section presents the result of survey concerning factors, or reasons, why farmers left a portion of their cropland unused in 1972. Only those factors which, according to survey and observation, had a relatively important impact on land utilization on Miami/Conover soils are studied.

As previously mentioned, there was about 784 acres (1.53 percent of total area) left idle by the farmers in the studied area. As part of the survey, a farmer who had idle cropland was questioned as to the reasons for such idleness. Table 6.3 shows the result of the survey. The most important factor limiting the use of Miami/Conover soils is poor drainage particularly for the Conover, followed by operator's age and speculation.

Table 6.3. Reasons for Putting Cropland Idle on Miami/ Conover Soils in 1972

Reasons	Cropland (Acre)	Percent
Land is too wet and needs tiling	308.50	39.36
Operators are too old and/or no interest in renting out	228.10	29.11
Land held for speculative purposes	149.90	19.13
Summer fallow	44.00	5.61
Discarded private airport	14.70	1.88
Land was cleared in 1972	11.00	1.40
Discarded pasture (livestock sold)	10.00	1.28
Inaccessible due to bridge damage	9.00	1.15
Farmer was hurt by tractor accident	8.50	1.08
Total Idle Land	783.70	100.00

As shown in the table, among the 783.70 acres of idle land, 308.50 acres (39.36 percent) was left idle due to poor drainage, 228.10 acres (29.11 percent) due to operator's age, and 149.90 acres (19.13 percent) due to speculation.

Other factors include mainly property rights, other physical reasons and a special farm practices. Apparently, physical and institutional factors are the most important reasons for idle land on Miami/Conover soils in south central Michigan. It should be noted that the cost of drainage is closely related with the outlet. If outlet exists, the cost of drainage is moderate--if it does not, costs are prohibitive.

Land Policy Implications

On the basis of information discussed above, and in view of the results of linear programming and functional analysis, together with farmers' options, the following land policy implications were derived to foster the more intensive or higher and better use of land resources, to encourage a farmer to get underutilized land into production, and at the same time, to discourage certain types of land use.[3]

1. The comparatively high returns to land, shown by both functional analysis and programmed solution, indicate that it would be profitable to expand farm size under the assumed conditions if one can obtain enough labor. As such, land prices in the studied area would continuously be bid

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[3] Both positive or nonnormative and normative information is required to obtain a prescriptive knowledge to solve the practical problems. In this study, the positive information includes land use situation, factors affecting the land use and the results of the functional analysis. The normative information, on the other hand, includes farmers' opinion, author's judgement and the results of linear programming.

up as farmers seek more land for farming in competition with nonagricultural uses.

The increase in the land price might have a cumulative adverse effect on agricultural sector. It might encourage land speculation and idle land would be held for such purpose,[4] on the other hand higher land prices would make it more expensive to hold idle land. Secondly, it would encourage a farmer to sell agricultural land once the point is reached where the salvage price of land exceeds the marginal value product of farm land. This could lead to desirable consolidation of holdings. Lastly, it would also discourage those planning to establish new farms.

2. The result of the study indicates that the demand for land for nonagricultural uses has increased significantly in the past few years. Apparently, the trend has been toward an increase in residential uses involving encroachment on farm land. This trend can easily be seen by observing the number of new residences in rural areas.

This encroachment has not yet caused serious inroads on the total agricultural production, nevertheless, it will have a cumulative adverse effect on crop production if it continues indefinitely.

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[4]In at least one case, this has actually occurred on a farm in Clinton county. A 7.4 acres of cropland was left idle for more than 10 years and gave rise to a serious insect and weed control problem for those who have land around the idle land.

A sound policy under this situation should focus on the maintenance of a proper balance between agricultural and nonagricultural uses of land. The policy should be designed to preserve the intrinsically best agricultural land and protect this land from the encroachment of non-agricultural uses while leaving agriculturally inferior land for residential and nonagricultural use. This objective can partly be attained by setting up zones of specified land use to avoid possible incompatibilities and conflicts between nonagricultural and agricultural uses of land.

3. The study shows that physical determinants, especially drainage are the most important factors limiting the use of agricultural land on Miami/Conover soils. As shown in Table 6.3, of the 784 acres of idle land, nearly 308 acres (40 percent) was left idle due to poor drainage. If the objective of land policy is greater crop acreage and more profitable agricultural use, it appears that some realignment in land use policy is necessary such as subsidized tiling of the wet land and land reclamation etc. to assist and encourage farmers in construction of drainage ditches and tiling wet land. Tax systems that favor private construction practices and subsidize the introduction and private acceptance of conservation measures could also be used.

4. The study shows that tenure arrangements in the studied area are not appropriate in the sense that the tenure period is too short (usually on a year-to-year basis)

and there are few written tenure agreements. These customary rental arrangements frequently give neither the tenant nor the landlord much reason for long term investment. Operators with limited tenure rights have little incentive for improving or maintaining the soil fertility or adopt drainage measure for long planning periods.

The government can play an important role in overcoming this problem. Specific programs can be developed to promote leasing and tenure arrangements that encourage investments in conservation practices.

Sound land tenure arrangements should provide incentives and means to stabilize resource productivity, equality of access to resources among individuals and efficient resource use.

5. One possible way to encourage a farmer to get underutilized land into production is to increase incentives with higher product prices. As part of the survey, data were collected from the farmers concerning the product prices that would induce farmers to bring more idle land (including woodland and plowable pasture land) into cultivation.[5] At this price combination, the programming results show that plowable pasture land was cleared up to the limit permitted by the model. This result tends to justify prices

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[5]The prices for each crop are listed in Case V in Table 4.10.

farmers thought were needed to give them an incentive to bring more land into cultivation.

It should be recognized that land policy has to be flexible to meet an inevitable change in social, political and economic conditions. Furthermore, it has to be realized that no single, rigid land policy can be devised which is applicable to any region. As such, land policy has to be adapted to meet the needs of separate regions.

Projected Consequences of Alternative Ways of Organizing the Use of Miami/Conover Soils

On the basis of the previous discussion of agricultural land utilization on Miami/Conover soils and the results of functional analysis and programmed solution, some tentative projections of farm land uses, potential acreage expansion and consequent returns etc. can be made under some assumptions.

The projected consequences are made based on the assumption that strong positive land policies such as a heavy tax on idle cropland, zoning, and subsidies are implemented by a government.

1. Agricultural production can be increased over 1972 through additional acreage of new land. By clearing and drainage, approximately 47,653 acres of additional new land could be pulled into production on the Miami/Conover soils in the two counties. Such land includes 24,016 acres (9.5 percent) of diverted land, most of which is now in production, 3,868 acres (1.53 percent) of idle cropland,

9,657 acres (3.82 percent) of plowable pasture land and 10,112 acres (4 percent) of woodland. Thus, the present expandable acreage is 23,637 acres. This projection is made by assuming that all diverted land has been brought back into production. Furthermore, it was assumed that about half of woodland rather than all woodland could be cleared and converted into cropland. Some farmers interviewed expressed the opinion that they were reluctant to clear the woodland because it was required for recreation purpose, preserving wildlife, and wood production.

It should be recognized that production would not increase in proportion of the acreage of new land because the study indicated that most of the unutilized land in the Ionia-Clinton area was poorer quality than the land normally used for row and grain crops. As previously discussed, the land is unused because it is inferior[6] in the first place; is idle because of the kind of ownership and change in value from a lower to a higher use; or has reverted due to poor drainage.

Increased use of presently idle land would likely be accomplished by expanding the size of existing farms. It would be unlikely that such land could be brought into production through establishing new farm due to the scattered location of the idle land coupled with the low labor returns

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[6]Land is inferior in terms of productivity and/or poor drainage.

which could not provide monetary incentives for new entrepreneurs.

2. Approximately $1,380,401 of earnings to land would be generated by bringing an additional 23,637 acres of new land into production on Miami or better soils in the two counties under 1973 price relationship. This figure is obtained by assuming that the actual increase in production through the crop use of idle, pasture land and woodland is 80 percent of the land normally used for row and grain crops (i.e., 23,637 x $73 x .80 where $73 is the adjusted estimate of marginal value product of land under 1973 price relationship).

3. Uses of agricultural land would not be fixed for certain crops or even nonfarm uses. They are expected to undergo continual shifts depending on changes in physical, economic, technological and institutional factors. Economic considerations indicate that more acreage would be devoted to wheat, field beans, corn and soybeans on cash crop farms at 1973 prices. Dairy and fatstock farms were not studied.

The programmed solution indicates the WB rotation dominates all other crop rotations on crop farms at fall 1973 price relationships. Furthermore, CCCCS and CB rotations entered the optimal solution for a large farm and medium* farm respectively (Table 4.3). On the other hand, CS rotation is in the least competitive position in the optimum plan (Table 4.6). Therefore, with the assumption of profit maximization as a single goal for a farmer, the trend would be more wheat and field beans production except perhaps on dairy and fatstock farms. It should be noted that the least competitive position of CS rotation does not necessarily lead to the conclusion that corn and soybean acreage would likely decrease. On the contrary, acreages of corn and soybean would tend to increase due to the comparative advantage of CCCCS rotation on a large crop farms. Corn is probably in a stronger position on dairy and fatstock farms.

However, care must be taken in applying the results derived from programming analysis, since the static linear programming model does not consider the overall aggregate effects of large scale adoption of optimal farm organization, risks and technology associated with field beans production, and internal rationing on the part of a farmer.

4. Land prices in the studied area can be expected to increase moderately due to: (a) comparatively high returns to land as indicated by both functional analysis and programmed solution, (b) inelastic nature of land supply schedule, (c) continued inflationary economy, and (d) continued demand for living space as population pressures increase. However, continual increasing production costs, reduced availability of labor and product price uncertainty might offset the rate of price increase to some extent.

5. Moderate farm size expansion would be expected as the estimated marginal value productivity of land in the studied area was found to be higher than return

estimated to be necessary to cover the cost of using the input. On the other hand, many acres of diverted land, idle cropland and pasture land could be brought into production as described in the previous section.

Since returns to the labor, operating expenditure and machinery were low as indicated by the functional analysis, an increase in the use of land would tend to increase the marginal earnings of machinery, operating expenditures and labor but at the same time would reduce the earning power of land at the margin. Consequently, higher farm income would be generated due to a better farm resource combination involving more land relative to machinery, and especially labor. However, continual increasing input costs such as fertilizers, machinery, wages, etc.; reduced availability of both skilled labor and entrepreneur; product price uncertainty; and nonexistence of economies to scale beyond 150 tillable acres would probably level off the trend of increasing farm size to some extent.

6. The possibility of establishing new farms is low due to: (a) the cost involved in establishing a new farm, (b) low returns to labor, cash expenditures and machinery even at 1973 farm product prices, (c) the scattered location of unused land, and (d) nonexistence of economies to scale beyond 150 tillable acres. As such, a continual decrease in the number of farm would be expected as average farm size is becoming larger and more efficient big machinery

is substituted for labor in the production process as agricultural wages increase.

7. Agricultural production can be increased through improvement of agricultural practices and intensification of cultivation on existing land in use, without the addition of new land, i.e., by selection and adaptation of crop varieties, appropriate use of fertilizers, better tilage, drainage, irrigation and control of water table. This point is repeatedly expressed by many farmers interviewed, though specific evidence was not obtained.

Whether or not product prices would change is unknown, since this study does not consider the overall aggregate effect of large scale adoption of optimal plan on both input and output market, and thus the programming analysis provides no direct information. However, it is conceivable that the supply curve of farm product would shift to the right over time, if some product expansion policy measures were enforced. Under this condition, farm product price would be depressed with consequent decline in farm income, given the inelastic demand for farm products.

On the other hand, the input price would increase as more inputs were required due to the expansion of farm size, giving rise to the cost-price squeeze in the agricultural sector. As such, although land policies might be effective in inducing expansion of farm size and consequent increase in production, they often give rise some adverse effects which create additional problems in the agricultural sector. Furthermore, the energy crisis induced by the oil embargo has heavily affected the agricultural sector with higher production costs. This factor also needs to be taken into consideration before adequate land policy is developed. Therefore, further studies are needed with respect to overall aggregate effect of the energy crunch, large scale adoption of optimal plan on both input and output markets.

CHAPTER VII

CONCLUSIONS AND IMPLICATIONS

The primary objective of this study was to ascertain profitable adjustments in the farm organization and land use for cash-grain farms in response to the increasing demand for agricultural products. Emphasis was placed on estimation of the marginal value productivities for various inputs and investments which would serve as a guide in planning the necessary changes in farm organization. Further, the general land use situation and the factors affecting the utilization of land in the Miami/Conover soils were studied.

Static linear programming was used to determine optimum farm plans with (1) farm resources fixed at initial level, (2) land, labor and machinery investment variable and (3) product prices variable. Investment/disinvestment theory was incorporated into situations (2) and (3). Farmers were stratified by age of operator and net worth as a major determinant for setting up representative farms. The former was used to measure their willingness and the latter was used to estimate their ability to make adjustments. Four representative farms: small, medium, large and medium* farms[1] were developed. The analysis was first given for Model I with cropland and associated durable resources fixed at 1972 levels. Secondly, the optimal organization was presented for Model II which permits variation in land resources and associated durable assets.

A production function of the Cobb-Douglas type was employed in deriving the estimates of marginal value productivities of inputs and investments on the selected farms. The data obtained from the sixty-one sample farms were used as a basis for three regression analyses. The first equation includes five variable input categories, i.e., land, labor, operating expenses, machinery investment, and buildings. In the second equation, buildings were omitted. An effort was made to examine the returns to scale by dividing the sample farms into two size groups. Examination of results lead to use of the third equation which forced constant returns to scale. Estimated coefficients were adjusted in a rough "Bayesian" way. Profitable reorganizations of farms was studied using the adjusted regression coefficients.

Since both linear programming and Cobb-Douglas function were used in this study, emphasis was focused on a

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[1]The medium* farm refer to the farms with net worth $80,000-$150,000 and operator's age over 55 years.

comparison of these two techniques, so as to be able to exploit fully their complementarities. In addition, an attempt was made to distinguish the more or less pseudo MVPs of linear programming from the true MVPs of continuous function which are partial derivatives of such functions.

The remainder of this chapter presents the major findings obtained from both the linear programming and functional analyses. In addition, results of the land utilization survey are also summarized. The implications of the study were drawn in such a way as to exploit the complementarities between the linear programming and Cobb-Douglas analyses. Lastly, suggested future studies are presented.

Linear Programming--Summary of Findings

The major findings of this part of the study may be summarized as follows:

1. The operators of representative farms in this area used all their initial capital and a considerable amount of the credit to make the indicated adjustments (Table 4.3). This implies that cash grain farmers were currently not fully utilizing their capital resources. As such, the representative farms studied were not organized to maximize profits.

2. The operators of representative farms in this area could profitably adopt a wheat-beans (WB) rotation under price conditions which existed in late 1973. The programmed solutions for Model I and Model II indicated that a WB rotation dominated each of the representative farm situations. However, CCCCS and CB rotations enter the optimal solution for the large farm and the medium* farm, respectively (Table 4.3). Even so, the corn-soybeans (CS) rotation was the least competitive in the optimum plans (Table 4.6).[2]

3. The programmed results indicate that land is the most limiting resource so long as off-farm work and migration are restricted. The high shadow price of land indicates that it would be profitable to expand farm size under assumed prices and output conditions if enough labor is fixed on the farm. The results also show that returns to land in the studied area were high, especially when compared with an annual rental rate of $30 per acre.[3] Furthermore, capital and labor were not fully utilized in

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[2]This result does not necessarily imply that corn and soybean acreages likely decrease. It merely indicates that CS rotation is in the weakest competitive position on cash crop farms among the crop rotations covered in the model and prices assumed. Acreages of corn and soybeans tend to increase due to the comparative advantage of CCCCS rotation on larger farms. Furthermore, corn is in a relatively stronger position on dairy and fatstock farms.

[3]The annual rental rates reported by farmers were probably low compared to what would actually have to be paid for farming purposes.

Model I where farm resources were fixed at initial levels (Table 4.1, 4.5).

4. No full-time hired worker was employed on the representative farm since family labor (including operator labor) was either adequate to meet all supervisory requirements or could not be paid for. However, some amounts of seasonal labor were employed in the optimal solution to supplement the family labor when it was completely used. The moderate increase in the use of unskilled seasonal labor was due primarily to expansions of farm size (Table 4.4).

5. In the optimum solution, all farms had some members with off-farm work, which agrees with what cash grain farmers were doing in the south central area in 1973. As opportunity cost of farm labor was high in the south central area of Michigan, it would be profitable for family members and operators to work off the farm as indicated in the programmed solution (Table 4.4). However, the constraints on off-farm work prevented the program from selling out the business to permit the farmer to accept full-time off-farm work.

6. The levels of land resource availability affected optimal farm organization and the competitive position of crop rotations. More crop rotations entered the optimum solutions when more land was acquired. As compared with

Model I, the provision of land rental and purchase opportunity not only resulted in increased net returns, but also changed the optimum combination of crop rotations (Table 4.3, 4.6, 4.8, 4.9).

7. Farm size would not be expected to expand without limit even under conditions of abundant land supply.[4] The results indicate that labor (including managerial labor) and capital are major restricting resources limiting expansion in farm size (Table 4.8).

8. More woodland and plowable pasture land would be cleared at the cost of $395 or less per acre and converted into cropland, if product prices remain high (fall 1973 price), with stable input prices and/or limited land were available for rental and purchase. Of the $395, clearance accounts for $245 per acre and tiling $150 per acre; thus drained and cleared plowable pasture can be brought into crop production merely by covering the opportunity cost of using it for pasture, which is probably not more than $20 per acre. However, no woodland would be cleared at the cost of $500 per acre in any representative farm situations studied. This indicates that converting woodland into cropland at the cost of $500 per acre is not economically justified, under the assumed prices and product conditions (Table 4.4, 4.8, 4.11).

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[4]The farm size expanded from 438 acres to 1,269 acres for a large farm (Table 4.8) under conditions of abundant land supply.

9. Product prices affect optimum farm plans and land use. The results indicate that wheat would leave the optimal organization if its price should fall to $3 per bushel with other crop prices constant at 1973 levels. CB and WB rotations enter the optimum plan to expand field bean production when field beans have a strong price advantage (Table 4.11, B-4, B-5, B-6).

10. The programming results tend to justify what farmers thought were prices needed to provide an incentive to bring more land into cultivation. The prices are presented in Table 4.10.

This study considers the optimum individual farm organizations. Macro analysis of the impact of widespread adoption of results was not considered.

Functional Analysis--Summary of Findings

On the basis of this phase of the study, the following statements can be made about Clinton-Ionia County cash-grain farms under the prevailing 1972 and 1973 marketing and production conditions.

1. Land on Clinton and Ionia county farms earned a fair rate of return during 1972. The unadjusted estimated marginal value product of tillable land was $46.84 which is higher than required to cover its marginal factor cost. The adjusted marginal earning of land was between $37 and $45 per acre in 1972 and $66 and $80 in 1973 (Table 5.12).

Since much cropland was either diverted by government set-aside programs or simply idle in 1972, an increase in crop area by expanding the extensive margin of cultivation was indicated for 1972 and 1973 conditions. An increase in the use of land per farm would tend to reduce its earning power at the margin but would, at the same time, increase the marginal earnings of machinery, operating expenditures, and labor.

2. Farm labor was earning a low rate of return in 1972. The estimated marginal value product of labor was found to be $309.57 per month, indicating that an increase of one month's work on the farm would be accompanied by an increase of $309.57 in gross income, holding other factor inputs constant at their respective geometric mean levels. This indicates that most cash-grain farms in the area studied are not able to compete with industry for hired labor and that off-farm work and/or migration was justified. Results of this study also indicate that the earning power of farm labor was still not high enough to compete with industrial wage rates even at the most favorable 1973 farm product prices. As such, few farmers could consider expanding their use of really reliable, high-paid, skilled labor. The return to labor can be increased by additional investments in land or using less labor relative to other inputs.

3. Cash operating expenditures were too great relative to the other categories of inputs, as reflected by the low

returns of this input category. This conclusion holds despite indications that the analysis somewhat underestimates the marginal value product of operating expenditure. The adjusted estimate of the marginal value product of operating expenses was slightly over a dollar ($1.01) for a dollar spent in 1972 which does not cover interest on the use of working capital for an average of six months. This suggests that care must be exercised in handling operating expenditures. The low earning power of productive cash expenses might be partly attributed to the high percentage (51 percent) of part-time farming among the 61 farms interviewed. Generally, a part-time farmer may tend to spend more cash for inputs in order to have more time for off-farm work.

4. The results of this study indicate that machinery was not used efficiently on farms in Clinton and Ionia counties during 1972, as reflected by the low returns found for this input category. Though the estimated marginal value product of machinery was probably biased downward, returns are still believed insufficient to cover the cost of using the input. The adjusted estimate of the marginal earning of machinery was between 12 and 21 cents per dollar per year in 1972 and 20 and 35 cents in 1973. This return hardly covers depreciation, interest, insurance, and maintenance which usually amount to at least 25 cents per dollar invested in machinery. The comparatively low return to

machinery reflected a large machinery investment of $16,886 for a typical farm which might profitably be reduced both relatively and absolutely. Therefore, further investment in machinery seems unprofitable unless land and other supporting inputs are also increased.

5. The empirical evidence indicates that economies to scale do not exist beyond 150 tillable acres at the farm-firm level[5] but that increasing returns to scale prevail for farms with less than 150 acres.

6. The results of this study show that the typical farm is not extremely maladjusted; however, improvement may often be obtained by some adjustment in the use of resources. The main adjustments needed seem to be: (1) to moderately increase farm size by expanding tillable acreage, (2) to reduce labor use, and (3) to be more careful in handling cash expenditure and machinery investment. An increase in the size of farm would tend to reduce the earning power of land at the margin, but at the same time would increase the marginal earning of machinery, operating expenditures and

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[5]The results of this study did not indicate that other than constant returns to scale prevail at the farm-firm level beyond 150 tillable acres. This fact does not necessarily lead to the conclusion that farm size would not grow beyond that level. Theoretically, increasing sizes of farms are possible under constant returns. However, the problems of consolidating small farms and buying out old farms at high acquisition costs for reliable labor are an important real world constraint on farm size.

labor. Consequently, higher farm income would be generated by larger size due to a better farm resource combination, involving more land relative to machinery and, especially, labor.

Some ways of reducing machinery investment have been noted, but much improvement in this direction cannot be assured because of indivisibility of machinery. An alternative organization of typical farms based on the adjusted regression coefficients and on the assumption of constant returns to scale was presented in the last part of Chapter V.

The results of the study provide a basis of estimating returns that might have been realized under the same conditions, but with different farm organization. However, future returns depend on future conditions of prices, technology, institutions, weather conditions and human factors. In applying the results of this study, these factors together with the limitations of the study previously mentioned must be taken into account.

Findings of the Land Utilization Survey

One of the objectives of this study was to identify the main factors limiting the utilization of more agricultural land on Miami/Conover soils in south-central Michigan. Another was to estimate potential land supplies and a third was to develop policy implications and consequences for alternative ways of using Miami/Conover soils. The approach was descriptive with emphasis on acreages of land used for various purposes, rather than on theoretical concepts. The major findings of this phase of the study may be summarized as follows:

1. Most Miami/Conover soils (68 percent) were used for crop production, including corn, legume-grass hay, wheat, soybean, field beans, oats and other crops. Also, fairly large areas were in woodland, accounting for 7.91 percent of the total area while pasture constituted 3.82 percent.

2. The most important physical factor limiting the use of Miami/Conover soil is poor drainage (particularly for the Conover), followed by operator's age, high off-farm wage rates and speculative investment. Other factors include property rights, other physical reasons and special farm practices.

3. Several land policy implications were derived from this study. They involve land prices, land utilization between the agricultural and nonagricultural sectors, land utilization in agriculture, institutional arrangements and product price policies (see Chapter VI for details).

4. Agricultural production could be increased through additional acreage of new land. By clearing and draining, a total of approximately <u>23,637 acres</u> of Miami/Conover soils could be pulled into production in the two counties.[6]

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[6]This figure does not include 24,016 acres (9.5 percent) of diverted land, most of which is now in production.

Such land includes 3,868 acres (1.53 percent) of idle cropland, 9,657 acres (3.82 percent) of plowable pasture land and 10,112 acres (4 percent) of woodland.

5. Approximately $1,380,400 of earnings to land would be generated by bringing an additional 23,637 acres of new land into production on Miami or better soils in the two counties under 1973 price relationships. This figure is obtained by assuming that the actual increase in production through crop use of idle, pasture land and woodland is 80 percent of that for land normally used for row and grain crops.

6. Uses of agricultural land will not be fixed for certain crops or even among nonfarm uses. Those are expected to undergo continual shifts depending on changes in physical, economic, technological and institutional factors.

7. Land prices in the studied area can be expected to increase moderately due to: (1) comparatively high returns to land as indicated by both functional analysis and programmed plans under 1972 and 1973 price relations, (2) the inelastic supply of land, (3) a continued inflationary economy, (4) continued demand for living space and population pressures increase and (5) loss minimizing on labor and equipment now fixed in agricultural use.

8. Moderate farm size expansion would be expected as the estimated margional value productivity of land in the

studied area was found to be higher than return estimated to be necessary to cover the cost of using the input. This trend may continue as larger and more efficient machines were developed and their adoption of these machines takes place.

9. Agricultural production can be increased through improvement of agricultural practices and intensified cultivation on existing land, without the addition of new land, i.e. by selection and adaptation of crop varieties, appropriate use of fertilizers, better tillage, drainage, and control of the water table.

Implications

The results of this study reveal important implications about the utilization of land and associated inputs for cash grain production. The programmed results indicated that it would be profitable to expand farm size under assumed restraints on off-farm work, assumed prices, and assumed output conditions. The functional analysis showed similar results, indicating that a moderate increase of farm size would be profitable if labor is available.

The desirability of expanding farm size as shown by both the linear programming and functional analyses imply that, given labor availability, higher farm income would be generated if more land were used relative to machinery, productive cash expenditure and especially labor. Probably land values in the studied area will continue to be bid up as farmers seek more land for farming along with the increase in demand for land for residential and industrial purposes. More unused cropland, and plowable pasture land can be expected to be brought into cultivation if product prices remain high with comparatively stable input prices.

Since quite a few acres of cropland (about 11 percent of total area) on Miami and Conover soils were either diverted by government set-aside programs or simply idle in 1972, an increase in crop area has probably occurred since the termination of government production control programs.

Adjustment in the utilization of agricultural land would be reflected in the structure of land use. Some farm land will probably be removed by residential, industrial and other nonfarm uses, but the relative decline will be small due to the considerable amount of potential cropland in the area studied. At the present time, the encroachment on farm land has not yet caused serious inroads on total agricultural production. Nevertheless, encroachment will have a cumulative adverse effect on crop production if it continues indefinitely. Under this situation, land-use policy should focus on the maintenance of an adequate balance between farm and nonfarm uses of land. The policy should be designed to preserve the intrinsically best farm land and protect this land from the encroachment of nonfarm uses while leaving agriculturally inferior land for residential and other uses.

Labor availability and use also affected expansion of farm size and adjustment in the utilization of farm land. Both the Cobb-Douglas study and the programmed results indicate that earnings to labor are lower than obtainable from off-farm employment. The study also indicated that the earning power of farm labor was not high enough to compete with industrial wage rates even at the most favorable 1973 farm product prices. As such, few farmers could consider expanding their use of really reliable, high-paid, skilled labor.

On the other hand, programmed results indicated that it would be profitable for family members and operators to work off the farm. The same results were obtained from the functional analysis. Under this situation, the majority of young rural people have been attracted by higher earnings of nonfarm work, and have left farming. This trend coupled with the continual retirement and other forces cause the total farm labor force to decline. Larger farm sizes and high labor costs imply that more capital is needed to replace labor. This indicates that there will be demand for capital to expand if labor is available (Table 4.3).

In an economic environment characterized by a strong demand for labor saving technology, the industrial sector responds by developing and producing a stream of such new machines. As larger, and more efficient machines are developed and adopted, impetus to increase farm sizes develops and creates some pressure on land prices. With reduced amount of total labor, an increase in the use of larger machines, the trend of increasing farm size may continue.

However, farm size should not be expected to expand without limit. The programmed results indicates that labor (including managerial labor) would eventually become a major restriction on expansion of farm size (Table 4.8, B-1, B-2, B-3). The trend toward increasing farm size will be offset by continual increasing inputs costs for machinery, fuel, herbicides, fertilizers etc.; reduced availability of both skilled labor and entrepreneurs; and product price uncertainty.

One question still remains to be answered. That is: the possibility and profitability of establishing a new cash grain farm in the area studied.

The results of this study imply that at prospective farm product and input prices, a farmer should not expected to receive simultaneously marginal earnings of $50 per acre on $500 an acre land to cover taxes, depreciation, interest and repairs on fences, tile, etc.; $9,600 per year for labor of the operator; 25 percent on machinery investment to cover interest, depreciation and repairs; and a $1.06 per dollar expended on fuel, lubricants, fertilizer, herbicides, etc., plus interest on the use of the committed money for an average of six months. Thus, the farm reorganizations suggested above are mainly for those who have substantial unrecoverable investments in their farms and for those who have committed their lives to cash crop farming on Miami or better soils in Clinton and Ionia counties and in similar central Michigan areas. Those capable of earning over $9,600 annually elsewhere should be extremely careful about leaving such employment to risk an investment of, say, $300,000 in land and machinery to establish new cash crop farm businesses unless they can find substantial tax management benefits, special stable product markets, or access to stable cheaper supplies of labor, fuel, fertilizer and/or other agro-chemicals and are able to obtain much higher yields than the typical farmer without increasing expenditures much beyond typical levels.[7]

Future Study Indicated

This study centered on the problems of resource productivities, farm organization and land utilization on the "heavy and lower" soil associations including Miami and

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[7]Lee, Yung-Chang and Johnson, Glenn L., "Are Central Michigan Cash Crop Farmers Getting Rich?" Michigan Farm Economics. Department of Agricultural Economics, Michigan State University, June, 1974, No. 377, p. 3.

Conover soils. Similar studies are needed on other locations in southern Michigan and on the "lighter and higher" soil associations including Hillsdale, Bellfontaine and Coloma. Emphasis should be placed on economic, physical, technological and institutional determinants of land use along with supply and demand considerations for farm products and farm inputs. The study would have to be multidisciplinary taking into account the utilization of advanced bio-chemical, irrigation and other technologies and the technical problems of roughage, food grain and feed grain and livestock production.

APPENDICES

APPENDIX A

Supplementary Tables

Table A-1. Initial Resource Restrictions for Representative Farms

Initial Resource	Unit	Operators Age			
		24 - 55 years			Over 55 yrs
		Small	Medium	Large	Medium*
Cropland	acre	93	156	438	211
Farm Labor in Season I	man hrs	1,144	1,236	2,024	1,268
Farm Labor in Season 2	"	583	632	1,072	703
Farm Labor in Season 3	"	637	660	1,101	703
Farm Labor in Season 4	"	286	324	516	317
Farm Labor in Season 5	"	572	618	1,058	706
Managerial Labor	Op. hrs	2,904	3,024	3,650	3,257
Annual Cash Account	$	4,275	4,412	13,714	9,286
Chattel Mortgage	$	5,394	8,616	19,120	5,600
Real Estate Mortgage	$	18,600	31,176	43,952	25,714
Operator Off-farm work	Hours	1,728	1,402	587	389
Family Off-farm work	"	384	565	411	365
Land Rented in Limit	acre	134	184	131	213
Land bought in Limit	"	117	82	54	114
Woodland	"	9	22	25	12
Pasture land	"	1.03	5.54	14.53	8.17
Power capacity (period 1)	Hours	280	280	280	280
Power capacity (period 2)	"	390	390	390	390
Power capacity (period 3)	"	180	180	180	180
Power capacity (period 4)	"	170	170	170	170
Power capacity (period 5)	"	200	200	200	200

Table A-2. Soybeans (2 years rotation) - Estimated Annual Costs and Returns Per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	5.50	25	137.50
II. Variable Cash Costs				
Seed	bu.	8.50	.83	7.06
Fertilizer ($N-P_2O_5-K_2O$)	bu.	.24-.19-.067	30+50+15	17.71
Herbicide (Amiben)	lb.	4.83	1	4.83
Power & Machinery Costs (Preharvest)	acre	5.86	1	5.86
Power & Machinery Costs (Harvest)	acre	3.56	1	3.56
Hauling	bu.	.10	25	2.50
III. Total Variable Cash Cost	$			41.52

Sources: (1) Costs and Returns for Major Cash Crops in Southern Michigan, revised by R.L.Meekhof, L.J. Connor and S.B. Nott, Dept. of Agri. Econ. M.S.U. September 1974, (2) Fertilizer Recomendations for Michigan Vegetables and Field Crops, by D. R. Christenson, R.E. Lucas and E.C. Doll, Crop and Soil Sciences Dept., M.S.U., Nov. 1972, and (3) Weed Control in Field Crops, by W.F. Meggitt, Dept. of Crop and Soil Sciences, M.S.U., January 1974.

Table A-3. Soybeans (3, 4, 5 years rotation) - Estimated Annual Costs and Returns Per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost (&)
I. Income				
Yield per acre	bu.	5.50	30	165.00
II. Variable Cash Costs				
Seed	bu.	8.50	.83	7.06
Fertilizer ($N-P_2O_5-K_2O$)	lb.	.24-.19-.067	40+25+25	16.02
Herbicide (Amiben)	lb.	4.83	1	4.83
Power & Machinery Costs (preharvest)	acre	5.86	1	5.86
Power Machinery Costs (Harvest)	acre	3.56	1	3.56
Hauling	bu.	.10	30	3.00
III. Total Variable Cash Cost	$			40.33

Sources: Same as Table A-2.

Table A-4. Corn (No cashcrop preceded) - Estimated Annual Costs and Returns Per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	2.25	90	202.50
II. Variable Cash Costs				
Seed	bu.	25.00	.21	5.25
Fertilizer ($N-P_2O_5-K_2O$)	lb.	.24-.19-.067	100+50+50	36.85
Herbicice Atrozme (80W)	lb.	2.30	2	4.60
Power & Machinery Cost (Preharvest)	acre	4.81	1	4.81
Power Machinery Cost (Harvest)	acre	4.40	1	4.40
Hauling	bu.	.10	90	9.00
III. Total Variable Cash Cost	$			64.91

Sources: Same as Table A-2.

Table A-5. Corn (preceded by cash crop) - Estimated Annual Costs and Returns per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	2.25	90	202.50
II. Variable Cash Costs				
Seed	bu.	25.00	.21	5.25
Fertilizer ($N-P_2O_5-K_2O$)	lb.	.24-.19-.067	100+50+25	35.18
Herbicide				
Bladex + Lasso	lb. + gal.	2.85 + 13.50	1 1/2 + 2 qt.	11.03
Power & Machinery Cost				
(preharvest)	acre	4.81	1	4.81
Power & Machinery Cost				
(harvest)	acre	4.40	1	4.40
Hauling		.10	90	9.00
III. Total Variable Cash				
Cost				69.67

Sources: Same as Table A-2.

Table A-6. Wheat (no cash crop preceded) - Estimated Annual Costs and Returns per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	4.25	45	191.25
II. Variable cash costs				
Seed	bu.	4.50	1.75	7.88
Fertilizer ($N-P_oO_5-K_2O$)	lb.	.24-.19-.067	45+75+25	26.73
Power & Machinery Cost				
Preharvest	acre	4.06	1	4.06
Power & Machinery Cost				
Harvest	acre	2.06	1	2.06
Hauling	bu.	.10	45	4.50
III. Total Variable Cash Cost				45.23

Sources: Same as Table A-2.

Table A-7. Wheat (preceded by cash crop)—Estimated Annual Costs and Returns per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	4.25	45	191.25
II. Variable Cash Cost				
Seed	bu.	4.50	1.75	7.88
Fertilizer ($N-P_2O_5-K_2O$)	lb.	.24-.19-.067	60+75+50	32.00
Power & Machinery Cost Preharvest	acre	4.06	1	4.06
Power & Machinery Cost Harvest	acre	2.06	1	2.06
Hauling	bu.	.10	45	4.50
III. Total Variable Cash Cost	$			50.50

Sources: Same as Table A-2.

Table A-8. Oats - Estimated Annual Costs and Returns per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	bu.	1.25	65	81.25
II. Variable Cash Costs				
Seed	bu.	3.50	2.25	7.88
Fertilizer ($N-P_2O_5+K_2O$)	lb.	.24-.19-.067	45+50+15	21.31
Herbicide (2,4-D)	lb.	6.00	.25	1.50
Power & machinery cost Preharvest	acre	6.39	1	6.39
Power & machinery cost Harvest	acre	2.05	1	2.05
Hauling	bu.	.10	65	6.50
III. Total Variable Cash Cost	$			45.63

Sources: Same as Table A-2.

Table A-9. Field Beans - Estimated Annual Costs and Returns per Acre

Item	Unit	Price or Cost/Unit ($)	Quantity	Value or Cost ($)
I. Income				
Yield per acre	cwt.	15.00	14	210.00
II. Variable Cash Costs				
Seed	bu.	45.00	.67	30.15
Fertilizer ($N-P_2O_5+K_2O$)	lb.	.24-.19-.067	40+25+50	17.70
Herbicide (Eptam)	lb.	2.41	2	4.82
Power & Machinery cost Preharvest	acre	11.08	1	11.08
Power & Machinery cost Harvest	acre	3.56	1	3.56
Hauling	bu.	.10	23.30	2.33
III. Total Variable Cash Cost	$			69.64

Souces: Same as Table A-2.

Table A-10. Assumed Fertilizer Requirements for Specified Cash Crop Enterprises by Soil Group, Southern Michigan[1/]

Crop	Soil Group			
	S_1 (Loam-Clay Loam)	S_2 (Loam-Clay Loam)	S_3 (Sandy Loam)	S_4 (Loamy Sand)
Corn for grain	120+60+50	100+50+50	80+25+50	70+0+50
Wheat	60+75+50	60+75+50	60+25+75	60+25+75
Oats	40+50+50	40+50+50	40+25+75	40+25+50
Soybeans	10+50+30	10+25+25	10+ 0 +50	10+0+25
Field beans	40+50+50	40+25+50	--	--
Alfalfa[2/]	0+50+75	0+50+75	0+25+75	0+25+75
Sugar beets	40+75+100	--	--	--

1/ The actual pounds of $N+P_2O_5+K_2O$ are specified. Inputs are based on the assumed yields in Appendix Table 2 and recommendations in: Fertilizer Recommendations for Michigan Vegetables and Field Crops, Michigan State University Extension Bulletin #-550, November -972. When the assumed yield did not coincide, interpolations were respectively made. Fertilizer inputs were based on the following soil test assumptions:

N - No legumes or manure

P - 20-39 pounds available per acre for loam-clay loams

- 40-59 pounds available per acre for sandy loams and loamy sands

K_1 - 120-159 pounds available per acre for loam-clay loams

- 120-169 pounds available per acre for sandy loams and loamy sands.

2/ Annual topdressing. Seeding fertilizer is charged to oats enterprise.

Source: R.L. Meekhof, L.J. Connor and S.B. Nott, Costs and Returns for Major Cash Crops in Southern Michigan, Agri. Econ. Report No. 277. Dept. of Agri. Econ. M.S.U. P. 26.

Table A-11. Estimated Labor Requirements Per Acre Per Month for Selected Cash Crops

Labor (Hrs) \ Crop	Corn	Soybeans	Wheat	Oats	Field Beans
March	.1	---	---	.4	---
April	1.2	.8	---	1.8	.4
May	2.1	1.6	---	---	1.2
June	.9	.7	---	.4	1.6
July	---	.9	1.1	.8	1.9
August	---	---	1.6	.4	.5
September	---	.8	1.8	---	2.4
October	.9	.8	---	.8	---
November	1.3	---	---	.4	---
Total Annual Labor	6.5	5.6	4.5	5.0	8.0

Source: Unpublished data, Department of Agricultural Economics, Michigan State University.

Table A-12. Estimated Annual Machine, Power, and Labor Requirements Per Acre for Specified Crop Enterprises, Southern Michigan

Crop and Operations	Dates	Times Over	Machine Time (hrs.)	Power Time (hrs.)	Labor Time (hrs.)
Corn - S_1 Soils					
Fertilize (bulk spreader)	3/15- 4/30	1		.07	.09
Plow (moldboard)	4/1 - 5/15	1	.46	.46	.47
Plant, fertilize, and spray	5/1 - 5/31	1	.45	.45	.59
Cultivate	5/25- 6/25	1	.35	.35	.36
Harvest (combine)	10/10-11/30	1	.85	.85	.94
Total Requirements			2.11	2.18	2.45
Corn - S_2, S_3 and S_4 Soils					
Fertilize (bulk spreader)	3/15- 4/30	1	---	.07	.09
Plow (moldboard)	4/1 - 5/15	1	.46	.46	.47
Plant and fertilize	5/1 - 5/31	1	.29	.29	.36
Spray	5/10- 6/10	1	.13	.13	.16
Cultivate	5/25- 6/25	1	.26	.26	.27
Harvest (combine)	10/10-11/30	1	.63	.63	.70
Total Requirements			1.77	1.84	2.05
Wheat					
Plow (moldboard)	8/1 - 8/31	1	.46	.46	.47
Disc (tandem)	8/15- 9/15	1	.18	.18	.18
Harrow (spring-tooth)	8/15- 9/15	1	.17	.17	.19
Drill and fertilize	9/10- 9/25	1	.44	.44	.52
Harvest (combine)	7/10- 7/30	1	.40	.40	.44
Total Requirements			1.65	1.65	1.80
Oats					
Plow (moldboard)	10/1 -11/20	1	.46	.46	47
Disc (tandem)	3/15- 4/15	1	.18	.18	18
Harrow (spring-tooth)	3/15- 4/15	1	.17	.17	.19
Drill and fertilize	4/1 - 5/1	1	.44	.44	.52
Spray	6/1 - 6/15	1	.13	.13	.16
Harvest (combine)	7/10- 8/10	1	.40	.40	.44
Total Requirements			1.78	1.78	1.96
Soybeans					
Plow (moldboard)	4/1 - 5/15	1	.46	.46	.47
Harrow (spring-tooth)	5/1 - 5/20	1	.17	.17	.19
Plant, fertilize, and spray	5/20- 6/10	1	.45	.45	.59
Cultivate	7/1 - 7/25	1	.35	.35	.36
Harvest (combine)	9/15-10/15	1	.55	.55	.61
Total Requirements			1.98	1.98	2.22
Field Beans					
Plow (moldboard)	4/15- 5/31	1	.46	.46	.47
Disc and spray (tandem)	5/20- 6/10	1	.21	.21	.23
Plant and fertilize	6/1 - 6/15	1	.39	.39	.48
Cultivate	7/1 - 7/30	2	.70	.70	.72
Pull and windrow	8/25- 9/25	1	.39	.39	.43
Harvest (combine)	8/25- 9/25	1	.55	.55	.61
Total Requirements			2.70	2.70	2.94

Source: L.J. Connor, Costs and Returns for Major Cash Crops in Southern Michigan, Agricultural Economics Report No. 87, Dept. of Agri. Econ. Michigan State University, 1967. P. 34.

Table A-13. Critical Planting and Harvesting Periods and Losses in Yield Resulting From Late Planting and Harvesting

Crop and Maximum Yield	Critical Period to Obtain Maximum Yield		Late Operations Causing Reductions in Yield	Yield Reductions								
				Number of Weeks Operation is Late								
	Planting	Harvesting		1	2	3	4	5	6	7	8	9
							(bushels)					
Corn 85 bu.	May 1-10	Oct. 5-15	planting	5	10	14						
			harvesting	1	2	3	5	7	10	15	20	25
Soybeans 28 bu.	May 15-25	Oct. 1-10	planting	1	2	5	13					
			harvesting	1.5	3.5	6.5	11.5	17.0				
Navy Beans 23 bu.	June 1-10	Aug. 25-Sept. 15	planting	1	2	5	13	20				
			harvesting	1.5	3.5	6.5	11.5	20	23			
Wheat 45 bu.	Sept. 16-25	July 10-20	planting	2	4	8	16	35	45			
			harvesting	2	4	9	20					

Source: Unpublished data, Department of Crop Science, Michigan State University.

Table A-14. Assumed Crop Yields, Fertilizer and Herbicide Requirements, and Other Production Practices for the Synthetic Cash-Grain Farm in Southern Michigan

Crop	Maximum Assumed Possible Yield	Seed Require-ments	Fertilizer Requirements $N-P_2O_5-K_2O$ 1/	Herbicide Require-ments	Other Production Practices: Operation	Times Over	Critical Time Period for Maximum Possible Yields 2/
	(bu./acre)	(bu.)	(lbs./acre)	(lbs./acre)			(dates)
Corn (38 in. rows)	85		80-0-0		bulk spread fertilizer	1	
					plow	1	
		.21	10-50-25		plant & fertilize	1	May 1 - May 10
				2 lbs. atrazine	spray	1	
					cultivate	1	
					harvest	1	Oct. 5 - Oct. 15
Soybeans (28 in. rows)	28				plow	1	
					harrow	1	
		.83	30-50-15	1 lb. amiben	plant, fertilize spray	1	May 15 - May 25
					cultivate	1	
					harvest	1	Oct. 1 - Oct. 10
Navy beans (28 in. rows)	23				plow	1	
				2 lbs. eptam	disc & spray	1	
		.67	30-50-15		plant & fertilize	1	June 1 - June 10
					cultivate	2	
					pull & windrow	1	
					harvest	1	Aug. 25 - Sept. 15
Wheat	45				plow	1	
					disc	1	
					harrow	1	
		1.75	45-75-25		drill & fertilize	1	Sept. 16 - Sept. 25
					harvest	1	July 10 - July 20

1/Quantities shown refer to actual pounds of nitrogen, phosphate, and potash, respectively.
2/Unpublished data, Department of Crop Science, Michigan State University.

Source: Larry J. Connor, Costs and Returns for Major Cash Crops in Southern Michigan, Agricultural Economics Report No. 87, Department of Agricultural Economics, Michigan State University, 1967.
G.L. Benjamin and L.J. Connor, Economies of Size of Machinery Systems on Southern Michigan Cash-Grain Farms, Agri. Econ. Report No. 112, Dept. of Agri. Econ. M.S.U.

Table A-15. TIME AVAILABLE FOR FIELD WORK BY CALENDAR PERIOD FOR WELL DRAINED SOILS

PERIOD	CALENDAR DAYS	% GOOD DAYS
APRIL 26 - MAY 10	16	45
MAY 11 - 18	8	37
MAY 19 - 26	8	65
MAY 27 - JUNE 3	8	70
SEPT. 27 - OCT. 17	21	53
OCT. 18 - NOV. 7	21	33
NOV. 8 - 28	21	14

Good days available depict the percent of days that historically have been available in 7 out of 10 years for well drained soils. In two years out of 10, fewer days will be available than depicted. Fall field days can be adjusted upward 10% for combining and picking operations.

Source: Unpublished Data, Department of Agricultural Economics, Michigan State University.

Table A-16. Number of Days Lost in a 6-Day Work Week Due to Inclement Weather

Climatic Week Calendar Period	No.	Ten Year Average Precipitation[1] (inch)	Number of Ten Hour Days Lost Per Week[2] (days)	Number of Hours Lost Per Week (hours)	Average Number of Hours Lost Per Day (hours)	Number of Days Lost in a Six-Day Work Week[3] (days)
April 1-17	1	.75	1.3	18	2.57	1.54
April 8-14	2	.28	.8	8	1.14	.68
April 15-21	3	.66	1.6	16	2.29	1.37
April 22-28	4	.73	1.8	18	2.57	1.54
April 29-May 5	5	.40	1.0	10	1.43	.86
May 6-12	6	.68	1.7	17	2.43	1.46
May 13-19	7	.42	1.0	10	1.43	.86
May 20-26	8	.30	.8	8	1.14	.68
May 27-June 2	9	.33	.8	8	1.14	.68
June 3-9	10	1.16	2.7	27	3.86	2.32
June 10-16	11	.91	2.2	22	3.14	1.88
June 17-23	12	.60	1.5	15	2.14	1.28
June 24-30	13	.36	.9	9	1.29	.77
July 1-7	14	.66	1.6	16	2.29	1.37
July 8-14	15	.44	1.1	11	1.57	.94
July 15-21	16	.57	1.4	14	2.00	1.20
July 22-28	17	.50	1.2	12	1.71	1.03
July 29-Aug. 4	18	.75	1.8	18	2.57	1.54
Aug. 5-11	19	.56	1.4	14	2.00	1.20
Aug. 12-18	20	.64	1.6	16	2.29	1.37
Aug. 19-25	21	.84	2.0	20	2.86	1.71
Aug. 26-Sept. 1	22	.70	1.7	17	2.43	1.46
Sept. 2-8	23	.41	1.0	10	1.43	.86
Sept. 9-15	24	.63	1.5	15	2.14	1.28
Sept. 16-22	25	.99	2.4	24	3.43	2.06
Sept. 23-29	26	.69	1.7	17	2.43	1.46
Sept. 30-Oct. 6	27	.50	1.2	12	1.71	1.03
Oct. 7-13	28	.45	1.1	11	1.57	.94
Oct. 14-20	29	.37	.9	9	1.29	.77
Oct. 21-27	30	.42	1.0	10	1.43	.86
Oct. 28-Nov. 3	31	.43	1.1	11	1.57	.94
Nov. 4-10	32	.47	1.2	12	1.71	1.03
Nov. 11-17	33	.60	1.5	15	2.14	1.28
Nov. 18-24	34	.26	.7	7	1.00	.60
Nov. 25-Dec. 1	35	.58	1.5	15	2.14	1.28

[1]Data pertains to the years 1958 to 1967. The information was obtained from the U.S. Weather Bureau, East Lansing, Michigan.

[2]Based on the regression line; Days Lost = .04 + 2.34 (In. of Precipitation).

[3]Values in column 5 are 6/10 of the values in column 4. Multiply by 6 to get the number of hours lost in a 6-day work week and divide by 10 to convert hours lost into days lost.

Source: G.L. Benjamin and L.J. Connor, Economies of Size of Machinery Systems on Southern Michigan Cash-Grain Farms, Agricultural Economics Report No. 112, Dept. of Agri. Econ., Michigan State University. P. 44.

Table A-17. Factors Used to Estimate Machine, Power, and Labor Requirements for Specified Field Operations in Southern Michigan

Operation	Width of Machine	Operating Speed	Field Efficiency[1/]	Acres/ Machine Hour 2/	Hrs./Acre /Time Over[3/]	Man Hrs. as Percent of Power Hrs.	Man Hrs./ Acre/Time Over
	(inches)	(MPH)	(percent)	(acres)	(hrs.)	(percent)	(hrs.)
Combine small grain (10 ft.)	120	3.0	70	2.52	.40	111	.44
Combine corn (two-row):							
38" rows	78	3.0	70	1.60	.63	111	.70
28" rows	56	3.0	70	1.18	.85	111	.94
Combine soybeans and field beans	112	2.5	65	1.82	.55	111	.61
Pick corn (two-row):							
38" rows	76	3.0	65	1.48	.68	111	.75
28" rows	56	3.0	65	1.09	.92	111	1.02
Harvest beets (two-row)	56	3.0	60	1.01	.99	111	1.10
Plow (4-16")	64	4.0	85	2.18	.46	102	.47
Plant & fertilize (four-row):							
38" rows	152	3.8	60	3.47	.29	124	.36
28" rows	112	3.8	60	2.55	.39	124	.48
Plant, fertilize & spray (four-row):							
38" rows	152	3.6	55	3.01	.33	132	.44
28" rows	112	3.6	55	2.22	.45	132	.59
Drill and fertilize (15-7")	105	3.3	65	2.25	.44	119	.52
Drill, fertilize, and spray (15-7")	105	3.1	60	1.95	.51	127	.65
Cultivate (four-row):							
38" rows	152	3.0	85	3.88	.26	104	.27
28" rows	112	3.0	85	2.86	.35	104	.36
Disc (12 ft.)	144	4.5	85	5.51	.18	102	.18
Disc and spray (12 ft.)	144	4.2	80	4.84	.21	110	.23
Harrow (12 ft.)	144	5.0	80	5.76	.17	108	.19
Windrow (12 ft.)	144	4.0	80	4.61	.22	100	.22
Mow (7 ft.)	84	4.0	80	2.69	.37	100	.41
Pull and windrow beans (four-row)	112	3.0	75	2.52	.39	110	.43

Table continued on next page.

Table A-17. continued

Operation	Width of Machine (inches)	Operating Speed (MPH)	Field Efficiency 1/ (percent)	Acres/ Machine Hour 2/ (acres)	Hrs./Acre /Time Over 3/ (hrs.)	Man Hrs. as Percent of Power Hrs. (percent)	Man Hrs./ Acre/Time Over (hrs.)
Top beets (three-row)	84	5.0	85	3.57	.28	100	.28
Bale hay	168	4.0	75	5.04	.20	111	.22
Mow-condition	84	3.8	75	2.39	.42	105	.44
Spray (six-row):							
38" rows	228	5.0	65	7.41	.13	125	.16
28" rows	168	5.0	65	5.46	.18	125	.23
Spread fertilizer (30 ft.)	360	5.0	80	14.40	.07	133	.09

1/ Field efficiency refers to the percentage of field time remaining for effective production after "lost time" has been deducted for such items as an adjustment, repairs, lubrication, and turning at ends.

2/ The capacity of field machines in acres per hour was computed as follows:

$$\frac{\text{(Machine width in inches) (Speed in MPH) (Field efficiency)}}{100} .$$

3/ Hours of machine and power time required to cover one acre.

Source: L.J. Connor, Costs and Returns For Major Cash Crops in Southern Michigan, Agricultural Economics Report No. 87, Department of Agricultural Economics, Michigan State University, 1967. pp. 32-33.

Table A-18. ESTIMATED HOURS OF FIELD OPERATION TIME REQUIRED FOR HARVESTING CORN WITH SELECTED MACHINES. 2/

Type of Harvesting Equipment	Harvesting Speed, M.P.H.	Field Efficiency	Acres per Hour	Machine Hours Required to Harvest: 100 Acres	Machine Hours Required to Harvest: Your Crop
(40-Inch Row Spacing)					
1-Row Picker	3.00	.67	.80	125	______
2-Row Picker	3.00	.65	1.56	65	______
2-Row Picker-Sheller	3.00	.67	1.61	63	______
2-Row Picker-Grinder	3.00	.65	1.56	65	______
2-Row Combine (Shell)	3.00	.70	1.68	60	______
2-Row Combine (Grind)	3.00	.67	1.61	63	______
3-Row Combine (Shell)	3.00	.70	2.52	40	______
3-Row Combine (Grind)	3.00	.67	2.41	42	______
4-Row Combine (Shell)	2.75	.65	2.86	35	______
4-Row Combine (Grind)	2.75	.62	2.73	37	______
(30-Inch Row Spacing)					
2-Row Picker	3.00	.65	1.17	86	______
2-Row Picker-Sheller	3.00	.67	1.21	83	______
2-Row Picker-Grinder	3.00	.65	1.17	86	______
3-Row Combine (Shell)	3.00	.70	1.89	53	______
3-Row Combine (Grind)	3.00	.67	1.81	56	______
4-Row Combine (Shell)	2.75	.65	2.15	47	______
4-Row Combine (Grind)	2.75	.62	2.05	49	______
6-Row Combine (Shell)	2.50	.65	2.93	35	______
6-Row Combine (Grind)	2.50	.62	2.79	36	______
(20-Inch Row Spacing)					
6-Row ~~Combine~~ (Shell)	2.50	.65	1.95	52	______
6-Row Combine (Grind)	2.50	.62	1.86	54	______
8-Row Combine (Shell)	2.50	.65	2.60	39	______
8-Row Combine (Grind)	2.50	.62	2.48	41	______

2/ Estimates based on 100 bushel corn yields. For yields of 125 bushels and over, increase the time for harvesting 100 acres by 10 per cent. For yields of 75 bushels or less, discount the time for harvesting 100 acres by 5 per cent.

Source: "Field Efficiency Guides" by R.G. White, Agricultural Engineering Department, Michigan State University, April, 1966.

Table A-19. Estimated New Costs, Description, Years and Hours of Use of Specified Power and Machinery Items, Southern Michigan

Item	Description	New Cost 1/	Years of Use 2/	Total Hours of Use 3/	Hours of Use Per Year 2/
		(dol.)	(yrs.)	(hrs.)	(hrs.)
Tractor	Diesel, 105 HP (PTO)	11,593	10	6,500	650
Tractor	Diesel, 64 HP (PTO)	9,305	10	6,500	650
Combine	12 ft. SP, with grain platform	11,500	10	2,000	200
Corn Head	Four-row	4,508	10	1,000	100
Corn Picker	Two-row, mounted	3,713	10	1,000	100
Baler	Size 14x18, PTO, twine tie	2,491	10	2,000	200
Bale Thrower		787	10	2,000	200
Beet Harvester	Two-row	8,450	8	1,200	150
Plow	6-16", semi-mounted, automatic	4,432	10	1,500	150
Corn & Bean Planter	Eight-row with fertilizer attachment	6,767	10	1,000	100
Grain Drill	16-10" with fertilizer attachment	2,193	12	804	67
Cultivator	Eight-row	2,367	10	1,500	150
Tandem Disc	12 ft.	1,657	12	1,200	100
Spring-tooth Harrow	12 ft.	403	15	1,500	100
Windrower	12 ft. (PTO)	1,709	8	1,200	150
Bean Puller	Four-row	825	10	1,000	100
Sprayer	Eight-row, pulltype with tank	622	10	1,200	120
Spray Attachment	Four-row	250	10	1,200	120
Beater-Topper	Four-row, double drum, rubber & steel flail	5,000	10	1,200	120
Mower-Conditioner	7 ft.	2,870	8	1,600	200
Mower	7 ft.	702	10	1,500	150
Grain Wagon	Grain box with tires, 8 ton	765	10	2,500	250

1/ Estimates of new costs and descriptions were obtained from machinery companies, local dealers, and from National Farm and Power Equipment Dealers Assoc., Official Guide, Tractors and Farm Equipment, Fall, 1974.

2/ Estimates were obtained from farmers enrolled in Michigan State University Telfarm Project.

3/ Years of use times annual hours of use.

Source: R.L. Meekhof, L.J. Connor and S.B. Nott, Costs and Returns For Major Cash Crops in Southern Michigan. Agri. Econ. Report No. 277, Dept. of Agri. Econ. M.S.U. Sept. 1974.

Table A-20. The Original Observations Obtained from Sixty-One Cash Grain Farms

Farm No.	X_1 Gross Income	X_2 Land (Acre)	X_3 Labor (Months)	X_4 Expenses ($)	X_5 Machine Investment ($)	X_6 Buildings ($)
1	21,318	205	5.90	5,520	32,083	15,500
2	47,351	368	9.80	15,997	50,388	36,000
3	39,531	358	14.00	12,541	30,853	23,000
4	2,691	38	1.00	438	3,100	2,800
5	2,238	29.40	2.50	801	6,155	1,200
6	2,922	46.30	2.00	1,125	6,350	7,500
7	48,158	476	20.00	11,480	33,600	16,500
8	13,685	110	8.00	3,480	17,800	5,000
9	6,880	78.20	7.50	2,423	6,530	9,250
10	11,415	117	11.00	3,188	6,365	3,200
11	2,267	49.30	1.70	1,736	3,632	3,150
12	4,279	51.60	2.00	1,767	5,930	2,500
13	9,383	110.70	4.00	5,420	17,700	10,000
14	12,572	145.60	8.00	3,315	7,250	2,800
15	5,324	94.60	9.00	4,697	2,730	150
16	13,546	112	6.00	4,813	17,800	3,000
17	5,190	49.50	6.00	1,535	7,305	2,700
18	7,280	100.30	4.00	2,453	7,750	6,000
19	10,521	57.50	6.00	3,677	14,150	3,000
20	21,927	251.48	11.60	6,834	23,605	15,400
21	23,317	298	12.00	8,806	27,580	10,800
22	10,672	83.60	10.00	3,773	17,000	4,000
23	10,896	110	8.00	4,296	19,175	17,500
24	5,518	60	7.00	2,842	6,100	3,800
25	7,338	80	7.00	4,525	16,200	2,000
26	55,456	336.60	10.00	15,321	62,100	12,000
27	17,553	136	7.10	3,512	10,050	4,500
28	24,543	145	12.00	5,566	8,702	7,500
29	19,116	234.50	8.00	6,904	17,259	7,500
30	24,870	303	10.00	8,613	29,250	18,500
31	17,566	135	11.00	4,905	15,275	8,500
32	29,544	206	6.00	9,957	44,100	30,500
33	7,209	45	2.00	1,870	7,900	2,000
34	11,134	76	8.00	3,200	11,150	3,500
35	2,131	22	2.50	600	12,500	3,000

Table A-20. Continued.

Farm No.	X_1 Gross Income	X_2 Land (Acre)	X_3 Labor (Months)	X_4 Expenses ($)	X_5 Machine Investment ($)	X_6 Buildings ($)
36	8,025	139	6.00	4,010	10,992	3,800
37	4,799	64	2.70	3,390	7,700	4,500
38	23,203	253	14.20	10,182	34,267	10,800
39	6,911	95.40	3.00	6,475	13,850	13,100
40	47,953	525	12.00	12,945	20,650	1,950
41	27,799	200	4.00	6,740	21,267	14,500
42	12,551	116	2.00	3,790	7,900	1,000
43	22,533	154	8.00	7,048	11,618	5,700
44	39,200	365.30	12.50	11,248	29,267	18,000
45	15,649	186	12.00	3,683	16,850	8,500
46	7,424	75	3.00	3,038	12,800	4,000
47	15,373	198	15.00	8,486	62,500	6,000
48	18,593	185.60	6.00	6,658	34,525	21,000
49	42,075	365	15.00	11,902	55,333	10,600
50	21,782	194	13.00	9,216	16,303	29,000
51	33,057	244	13.00	8,634	31,629	10,500
52	189,396	1800	32.00	53,170	91,019	8,000
53	16,441	163.10	6.00	9,680	18,850	6,500
54	20,614	207	8.00	4,572	15,750	20,400
55	20,275	192	8.00	7,432	20,117	3,700
56	166,492	1386	27.85	45,981	93,375	61,700
57	10,388	140	9.50	5,722	23,613	8,000
58	19,827	163	12.00	11,337	30,243	16,500
59	21,493	245	10.00	8,195	27,400	6,890
60	30,486	272.55	10.00	12,801	29,262	15,150
61	25,531	232	8.00	14,419	59,979	3,500

APPENDIX B

Optimum Farm Organization for Small, Medium and Medium*
Size Representative Farms (Model II)

Table B-1. Summary of Optimum Land Use, Resource Transactions and Shadow Prices Under Various Levels of Land Resources on Small Cash Grain Farm (Model II)

	Unit	Case I	Case II	Case III	Case IV	Case V
Net Return	$	32,319	35,426	44,725	54,927	63,824
Crop Rotation						
WB	acre	154	193	344	494	622
Credit used	$	2,853	15,811	63,678	52,123	31,612
Resources obtained or sold						
Mgr. labor hired	hour	—	—	—	1,026	2,105
Unskilled labor hired	Man hrs	—	—	380	683	844
Mgr. labor sold	hour	1,728	1,728	1,052	1,299	1,687
Family labor sold	hour	315	77	268	384	384
Land A rented	acre	30	50	134	134	134
Land A purchased	"	30	50	117	67	—
Land B rented	"	NA	NA	NA	200	395
Land B purchased	"	NA	NA	NA	—	—
Woodland cleared	"	—	—	—	—	—
Plowable pasure cleared	"	1	—	—	—	—
Shadow Prices						
Cropland	$/acre	120	107	101	81	35
Land A for rent	"	90	77	71	51	5
Land A for purchase	"	66	53	40	—	—
Land B for rent	$/acre	NA[a]	NA	NA	46	—
Land B for purchase	"	NA	NA	NA	—	—
April-May labor	$/hr.	.44	.44	—	—	2.89
June-July labor	$/hr.	.44	.44	.50	1.70	5.35
August labor	"	—	—	.50	1.70	5.35
Sept.-Nov. labor	"	—	—	.50	1.70	5.35
Cash	$	.09	.09	.11	.23	.78
Chattel Mortgage	"	—	—	.01	.11	.61
Real Estate Mortgage	"	—	—	.02	.13	.64
Managerial Labor	$/hr.	—	2.56	2.85	4.30	6.22
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	.39	—	—	—	—

[a] NA denotes does not apply.

Table B-2. Summary of Optimum Land Use, Resource Transactions and Shadow Prices Under Various Levels of Land Resources on Medium Cash Grain Farm (Model II)

	Unit	Case I	Case II	Case III	Case IV	Case V
Net Return	$	39,624	42,768	54,559	65,787	78,201
WB	acre	222	262	422	622	649
CCS	"	—	—	—	—	177
Credit used	$	8,356	21,514	49,376	74,370	50,940
Resources obtained or sold						
Mgr. labor hired	hour	—	—	103	1,663	2,671
Unskilled labor hired	man hrs	—	—	647	956	1,154
Mgr. labor sold	hour	1,402	1,402	904	1,402	1,402
Family labor sold	hour	508	258	565	565	565
Land A rented	acre	30	50	184	184	184
Land A purchased	acre	30	50	82	82	—
Land B rented	acre	NA[a]	NA	NA	200	486
Land B purchased	acre	NA	NA	NA	—	—
Woodland cleared	acre	—	—	—	—	—
Plowable pasture cleared	acre	6	6	—	—	—
Shadow Prices						
Cropland	$/acre	120	120	95	83	35
Land A for rent	"	90	90	65	53	5
Land A for purchase	"	67	67	38	14	—
Land B for rent	"	NA	NA	NA	48	—
Land B for purchase	"	NA	NA	NA	—	—
June-July labor	$/hr	.22	.22	1.51	3.49	5.27
August labor	$/hr	—	—	1.51	3.49	5.27
Sept.-Nov. labor	"	—	—	1.51	3.49	5.27
Cash	$	.09	.09	.09	.16	.76
Chattel mortgage	$	—	—	—	.05	.59
Real Estate mortgage	$	—	—	.01	.06	.61
Managerial labor	$/hr.	—	—	3.81	5.00	6.9[illegible]
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	1.00	1.00	—	—	—

[a] NA denotes the item is not applicable.

Table B-3. Summary of Optimum Land Use, Resource Transactions and Shadow Prices Under Various Levels of Land Resources on Medium* Cash Grain Farm (Model II)

	Unit	Case I	Case II	Case III	Case IV	Case V
Net Return	$	40,820	44,480	62,057	71,445	78,079
Crop Rotation						
WB	acre	279	319	422	570	666
CB	"	—	—	116	—	—
CCCCS	"	—	—	—	107	—
CCS	"	—	—	—	—	114
Credit Used	$	14,129	26,962	75,306	59,184	42,791
Resources obtained or sold						
Mgr. labor hired	hour	—	—	—	570	1,071
Unskilled labor hired	man hrs	—	49	1,125	1,430	1,723
Mgr. labor sold	hour	389	389	389	389	389
Family labor sold	hour	365	365	365	365	365
Land A rented	acre	30	50	213	213	213
Land A purchased	"	30	50	114	53	—
Land B rented	"	NA	NA	NA	200	356
Land B purchased	"	NA	NA	NA	—	—
Woodland cleared	"	—	—	—	—	—
Plowable pasture cleared	"	8	8	—	—	—
Shadow Prices						
Cropland	$/acre	137	126	109	78	35
Land A for rent	$/acre	107	96	79	48	5
Land A for purchase	"	84 a/	73	39		
Land B for rent	"	NA	NA	NA	43	—
Land B for purchase	"	NA	NA	NA	—	—
April-May labor	$/hr.	—	—	—	.18	1.80
June-July labor	"	—	3.26	3.49	3.65	5.17
August labor	"	—	3.26	3.49	3.65	5.17
Sept.-Nov. labor	"	—	—	3.49	3.65	5.17
Cash	$	.09	.09	.16	.22	.72
Chattel mortgage	"	—	—	.05	.10	.56
Real Estate mortgage	"	—	—	.07	.12	.59
Mgr. labor	$/hr.	—	—	—	5.20	7.12
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	18	7	—	—	—

a/ NA denotes does not apply.

Table B-4. Summary of Optimum Land Use, Resource Transaction and Shadow Prices for Selected Resources on Small Cash Grain Farm (Model II)

Price Combination	Unit	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low wheat Price)	Case V (Farmer's Desired Price)
Corn Price	$/bu.	1.80	2.25	2.48	2.25	2.34
Soybean price	"	4.40	5.50	6.05	5.50	5.34
Wheat price	"	2.13	4.25	4.25	3.00	4.03
Oats price	"	.90	1.25	1.38	1.25	1.49
Field beans price	$/cwt.	12.00	15.00	19.50	15.00	18.09
Net Return	$	25,338	35,426	41,525	32,913	38,649
CBS	acre	193	—	—	45	—
CB	"	—	—	—	148	—
WB	"	—	193	194	—	194
Credit used	$	18,547	15,811	16,320	19,543	16,320
Resources acquired						
Mgr. labor hired	hour	—	—	—	—	—
Unskilled labor hired	man hrs	—	—	—	—	—
Land rented	acre	50	50	50	50	50
Land purchased	"	50	50	50	50	50
Woodland cleared	"	—	—	—	—	—
Plowable pasture cleared	"	—	—	1	—	1
Off-farm employment						
Mgr. labor	hour	1,666	1,724	1,719	1,605	1,719
Family labor	"	54	77	75	42	75
Shadow prices						
Cropland	$/acre	54	107	138	92	124
Rented land	"	24	77	108	62	94
Purchased land	"	.68	53	85	36	70
April-May labor	$/hr.	.44	.44	2.99	.47	.44
June-July labor	"	.44	.44	2.99	.47	.44
August labor	"	—	—	2.55	—	—
Sept.-Nov. labor	"	—	—	2.55	—	—
Cash	$	.09	.09	.09	.09	.09
Chattel mortgage	"	—	—	—	—	—
Real Est. mortgage	"	—	—	—	.01	—
Mgr. labor	$/hr.	2.56	2.56	2.56	2.56	2.56
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	—	—	19	—	4.26

Table B-5. Summary of Optimum Land Use, Resource Transaction and Shadow Prices for Selected Resources on Medium Cash Grain Farm (Model II)

Price Combination	Unit	Case I (Low Price)	Case II (Fall 1973 price)	Case III (High price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
Corn price	$/bu.	1.80	2.25	2.48	2.25	2.34
Soybean price	$/bu.	4.40	5.50	6.05	5.50	5.34
Wheat price	"	2.13	4.25	4.25	3.00	4.03
Oats price	"	.90	1.25	1.38	1.25	1.49
Field beans price	$/cwt.	12.00	15.00	19.50	15.00	18.09
Net Return	$	29,546	42,768	51,112	39,686	47,132
CBS	acre	234	—	—	82	—
CB	"	22	—	79	174	69
WB	"	—	262	183	—	193
Credit used	$	23,050	21,514	22,212	25,149	22,095
Resources acquired						
Mgr. labor hired	hour	—	—	—	—	—
Unskilled labor hired	man hour	—	—	—	5	—
Land rented	acre	50	50	50	50	50
Land pur.	"	50	50	50	50	50
Woodland cleared	"	—	—	—	—	—
Plowable pasture cleared	"	—	6	6	—	6
Off-farm employment						
Mgr. labor	hour	1,402	1,402	1,402	1,402	1,402
Family labor	hour	166	258	179	87	190
Shadow prices						
Cropland	$/acre	66	120	152	94	137
Rented land	"	36	90	122	64	107
Purchased land	"	12	67	98	41	84
April-May labor	$/hr.	3.10	.22	2.77	.71	2.77
June-July labor	"	2.83	.22	2.77	.44	2.77
August labor	"	2.38	—	2.55	—	2.55
Sept.-Nov. labor	"	2.38	—	2.55	—	2.55
Cash	$	.09	.09	.09	.09	.09
Chattel mortgage	"	—	—	—	—	—
Real Est. mortgage	$	—	—	—	—	—
Managerial labor	$/hr.	2.56	—	—	1.78	—
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	—	1.00	33	—	17.66

Table B-6. Summary of Optimum Land Use, Resource Transaction and Shadow Prices for Selected Resources on Medium* Cash Grain Farm (Model II)

Price Combination	Unit	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
Corn price	$/bu.	1.80	2.25	2.48	2.25	2.34
Soybean price	"	4.40	5.50	6.05	5.50	5.34
Wheat price	"	2.13	4.25	4.25	3.00	4.03
Oats price	"	.90	1.25	1.38	1.25	1.49
Field beans price	$/cwt.	12.00	15.00	19.50	15.00	18.09
Net Return	$	28,649	44,480	55,155	41,337	50,185
CBS	acre	195	—	—	—	—
CB	"	116	—	178	311	178
WB	"	—	319	141	—	141
Credit used	$	28,660	26,962	29,197	31,848	29,197
Resources acquired						
Mgr. labor hired	hour	—	—	—	—	—
Unskilled labor hired	manhour	68	49	13	84	13
Land rented	acre	50	50	50	50	50
Land purchased	"	50	50	50	50	50
Woodland cleared	"	—	—	—	—	—
Plowable pasture cleared	"	—	8	8	—	8
Off-farm employment						
Mgr. labor	hour	389	389	389	389	389
Family labor	"	365	365	365	365	365
Shadow prices						
Cropland	$/acre	75	126	161	110	146
Rented land	"	46	96	131	80	116
Purchased land	"	20	73	105	53	90
April-May labor	$/hr.	3.28	—	—	3.28	—
June-July labor	"	—	3.26	3.28	—	3.28
August labor	"	—	3.26	—	—	—
Sept.-Nov. labor	"	—	—	—	3.28	—
Cash	$	.09	.09	.09	.09	.09
Chattel mortgage	"	—	—	—	—	—
Real Est. mortgage	"	.01	—	.01	.01	.01
Managerial labor	$/hr.	—	—	—	—	—
Woodland	$/acre	—	—	—	—	—
Plowable pasture	"	—	6.97	41	—	25.85

Table B-7. Shadow Price of a Unit of an Excluded Crop Rotation Under Various Land Resource Levels on Small Cash Grain Farm (Model II)

Crop Rotation	Case I	Case II	Case III	Case IV	Case V
CB	4.52	14.70	8.85	7.06	15.51
CS	36.68	26.15	36.54	33.14	31.10
WS	31.00	10.30	26.21	22.98	5.14
CBW	1.97	8.56	1.99	3.80	11.15
CBS	13.54	3.48	17.94	9.75	.11
COW	.63	---	---	8.27	5.16
BCO	15.95	22.48	25.08	29.05	37.31
CBO	10.98	17.52	20.06	23.74	30.69
SCO	17.28	---	22.20	23.41	12.75
CCB	9.00	25.76	14.18	18.38	53.27
CCS	7.05	---	7.14	4.17	---
CCCB	2.31	25.66	6.57	7.87	28.62
CCCS	3.53	3.06	3.57	2.08	3.82
CCBW	3.53	16.70	3.57	7.17	21.84
CCOW	---	5.95	.25	---	---
CCBS	13.55	10.08	18.57	12.07	4.81
CCCBW	---	19.76	---	5.09	25.65
CCCCS	---	6.12	---	---	7.63
CCCBS	11.45	14.57	15.83	10.89	14.37

Table B-8. Shadow Price of a Unit of an Excluded Crop Rotation Under Various Land Resource Levels on Medium Cash Grain Farm (Model II)

Crop Rotation	Case I	Case II	Case III	Case IV	Case V
CB	4.06	8.63	13.25	7.75	13.51
CS	36.66	27.72	24.64	29.49	31.82
WS	31.44	17.93	10.15	19.56	8.23
CBW	1.97	6.54	9.20	4.66	9.02
CBS	13.09	1.45	.77	6.54	2.35
COW	.69	---	---	1.51	5.44
BCO	15.09	14.39	21.65	25.75	37.63
CBO	10.12	9.43	16.66	20.60	31.08
SCO	16.91	---	---	16.37	17.22
CCB	8.53	17.68	25.15	17.53	48.17
CCS	7.06	---	---	2.09	NA[a]
CCCB	1.84	15.56	25.45	10.57	22.47
CCCS	3.53	1.04	3.68	1.04	1.75
CCBW	3.53	12.68	17.99	8.91	17.63
COOW	---	3.88	3.25	---	---
CCBS	13.46	6.39	8.67	9.94	7.82
CCCBW	---	13.73	21.67	7.86	19.38
CCCCS	---	2.09	7.36	---	3.50
CCCBS	10.99	8.51	13.11	9.60	12.41

[a]NA denotes the item is not applicable.

Table B-9. Shadow Price of a Unit of an Excluded Crop Rotation Under Various Land Resource Levels on Medium* Cash Grain Farm (Model II)

Crop Rotation	Case I	Case II	Case III	Case IV	Case V
CB	1.92	4.66	NA[a]	7.44	12.94
CS	30.53	28.12	32.52	30.65	31.84
WS	27.45	22.29	30.35	20.31	9.22
CBW	4.71	5.33	3.60	4.53	8.53
CBS	---	.25	3.02	7.10	2.71
COW	.33	---	1.91	2.92	7.00
BCO	4.97	8.88	12.76	27.26	38.76
CBO	---	3.91	7.61	21.99	32.27
SCO	.71	---	14.29	19.00	19.35
CCB	9.13	12.49	8.72	18.99	46.06
CCS	1.59	.34	4.20	2.63	NA
CCCB	5.17	9.17	.71	9.77	21.07
CCCS	.79	.17	2.10	1.31	1.35
CCBW	9.00	10.25	6.78	8.68	16.68
CCCW	2.64	2.94	---	---	---
CCBS	3.46	4.33	5.42	10.31	7.29
CCCBW	8.20	10.08	4.68	7.37	18.02
CCCCS	---	---	---	NA	2.70
CCCBS	3.38	4.87	3.97	9.75	11.89

[a]NA denotes the item is not applicable.

Table B-10. Shadow Price of One Unit of an Excluded Rotation Under Various Price Combinations--Small Farm (Model II)

Crop Rotation	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
CB	2.16	14.70	---	NA[a]	---
CS	23.75	26.15	57.55	31.39	50.16
WB	---	NA	NA	---	NA
WS	29.63	10.30	56.39	30.25	49.00
CBW	6.87	8.56	25.36	6.77	20.44
CBS	NA	3.48	---	NA	---
COW	4.17	---	39.87	8.30	35.64
BCO	4.97	22.48	4.97	4.98	4.97
CBO	---	17.52	---	---	---
SCO	2.46	---	25.20	6.70	20.28
CCB	11.53	25.76	27.87	9.48	22.95
CCS	5.67	---	44.82	7.63	34.98
CCCB	9.74	25.66	44.57	7.35	34.73
CCCS	7.04	3.06	64.69	8.88	49.93
CCBW	13.39	16.70	50.31	13.20	40.47
CCOW	10.88	5.95	68.24	14.92	53.48
CCBS	2.67	10.08	19.83	5.57	18.48
CCCBW	14.76	19.76	70.18	14.45	55.42
CCCCS	5.37	6.12	84.56	11.79	64.88
CCCBS	7.70	14.57	44.70	7.49	34.86

[a]NA denotes does not apply.

Table B-11. Shadow Price of One Unit of an Excluded Rotation Under Various Price Combinations--Medium Farm (Model II)

Crop Rotation	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
CB	NA[a]	8.63	NA	NA	NA
CS	27.02	27.72	59.78	33.15	54.41
WB	---	NA	NA	---	NA
WS	35.41	17.93	58.62	32.11	53.25
CBW	8.01	6.54	27.27	8.63	24.46
CBS	NA	1.45	---	NA	---
COW	5.52	---	43.68	12.02	38.07
BCO	4.97	14.39	4.97	4.97	4.97
CBO	---	9.43	---	---	---
SCO	7.92	---	27.12	8.54	24.31
CCB	10.51	17.68	29.77	11.13	26.96
CCS	10.11	---	48.63	11.36	43.02
CCCB	9.86	15.56	48.38	11.11	42.77
CCCS	12.62	1.04	70.40	14.50	61.99
CCBW	15.67	12.68	54.13	16.92	48.52
CCOW	18.62	3.88	76.09	20.50	65.49
CCBS	---	6.39	22.10	7.11	19.29
CCCBW	18.18	13.73	75.90	20.06	67.49
CCCCS	11.99	2.09	93.70	19.30	80.95
CCCBS	9.98	8.51	48.51	11.24	42.90

[a]NA denotes does not apply.

Table B-12. Shadow Price of One Unit of an Excluded Rotation Under Various Price Combinations--Medium* Farm (Model II)

Crop Rotation	Case I (Low Price)	Case II (Fall 1973 Price)	Case III (High Price)	Case IV (Low Wheat Price)	Case V (Farmer's Desired Price)
CB	NA[a]	4.66	NA	NA	NA
CS	33.53	28.12	86.41	39.89	53.11
WB	---	NA	NA	---	NA
WS	36.40	22.29	85.17	38.65	51.88
CBW	14.41	5.33	27.86	14.47	22.94
CBS	NA	.25	31.08	---	---
COW	23.57	---	50.47	16.49	40.63
BCO	4.98	8.88	4.98	4.98	4.98
CBO	---	3.91	---	---	---
SCO	14.30	---	58.80	14.36	22.79
CCB	17.11	12.49	30.56	17.18	25.64
CCS	22.90	.34	80.88	23.03	39.96
CCCB	22.63	9.17	49.53	22.76	39.69
CCCS	31.79	.17	103.22	31.99	57.38
CCBW	28.43	10.25	55.30	28.57	45.46
CCOW	37.75	2.94	78.03	37.95	63.27
CCBS	7.94	4.33	58.40	9.35	22.40
CCCBW	37.32	10.08	77.64	37.52	62.88
CCCCS	40.13	---	127.06	42.45	76.30
CCCBS	22.76	4.87	80.75	22.90	39.82

[a]NA denotes does not apply.

Table B-13. Enterprise Levels by Representative Farm in 1972

Crops	Unit	Operator's Age			
		24 to 55 Years			Over 55 Years
		Small	Medium	Large	Medium*
Corn	Acre	18	45.29	136.24	38.14
Soybeans	Acre	25.30	15.71	37.29	15.43
Wheat	Acre	13.40	15.47	55.00	40.14
Oats	Acre	0	4.00	23.57	3.14
Field Beans	Acre	10.70	31.76	102.14	68.57
Hay	Acre	3.60	12.06	22.86	5.71
Other Crops[a]	Acre	2.10	10.06	7.71	0

[a]Other crops include sugar beets, cucumber, etc.

Table B-14. Initial and Optimum Inventories of Machinery--Small Farm (Model II)

Item	Initial Inventory	Purchased	Sold	Optimum
Tractor 1 (53 H.P.)	1		.55	.45
Tractor 2 (70 H.P.)	1			1
4-bottom plow	1		.21	.79
Disc 1 (12')	1			1
Disc 2 (16')	0	.03		.03
Planter (4 row)	1			1
Cultivator (4 row)	1		.06	.94
Grain drill(13 holes)	1			1
Grain drill (16'-17")	0	.79		.79
Corn picker (2 row)	1		1	0
Combine (2 row) pull type	1		.18	.82
Spring tooth 12'	1		.27	.73

Table B-15. Initial and Optimum Inventories of Machinery--Medium Farm (Model II)

Item	Initial Inventory	Purchased	Sold	Optimum
Tractor (53 H.P.)	1		.45	.55
Tractor (70 H.P.)	1			1
4-bottom plow	1		.03	.97
Disc 1 (12')	1			1
Disc 2 (16')	0	.21		.21
Planter (4 row)	1			1
Cultivator (4 row)	1		.08	.92
Grain drill (13 holes)	1			1
Grain drill (16'-17")	0	.97		.97
Corn Picker (2 row)	1		1	0
Combine (pull type)	1			1
Spring tooth 12'	1		.34	.66

Table B-16. Initial and Optimum Inventories of Machinery--Large Farm (Model II)

Item	Initial Inventory	Purchased	Sold	Optimum
Tractor (70 H.P.)	1		.10	.90
Tractor (115 H.P.)	1			1
6 bottom plow	1			1
4 bottom plow	0	1.72		1.72
Disc 1 (12')	1			1
Disc 2 (16')	0	1.70		1.70
Planter (6 row)	1		.40	.60
Cultivator (4 row)	1		.20	.80
Grain drill (16'-17")	1	.26		1.26
Combine (13',4 row)	1			1
Spring tooth (16')	1		.71	.29
Combine (10',2 row)	0	.10		.10

Table B-17. Initial and Optimum Inventories of Machinery--Medium* Farm (Model II)

Item	Initial Inventory	Purchased	Sold	Optimum
Tractor (53 H.P.)	1		.30	.70
Tractor (70 H.P.)	1			1
3-bottom plow	1			1
4 bottom plow	0	.75		.75
Disc (12')	1			1
Disc (16')	0	.74		.74
Planter (4 row)	1			1
Cultivator (4 row)	1		.04	.96
Grain drill (13 hole)	1			1
Grain drill (16'-17")	0	.84		.84
Corn picker (2 row)	1		.35	.65
Combine (pull type)	1			1
Spring tooth (12')	1		.49	.51

APPENDIX C

Questionnaires Used in Personal Interviews

Land Area____________
Farm No.____________
Tel. No.____________
Enumerator____________
Date____________

Confidential

Michigan State University
Department of Agricultural Economics
East Lansing, Michigan

Farm Management Survey

About what percent of your 1972 gross farm sales (income) from the farm came from:

Cash grain________% Livestock________%

Other Sales________% Kind____________

If "cash grain" is less than 50%, use "Land Utilization" Questionnaire.

I. Farm Size

How many acres did you operate?____________

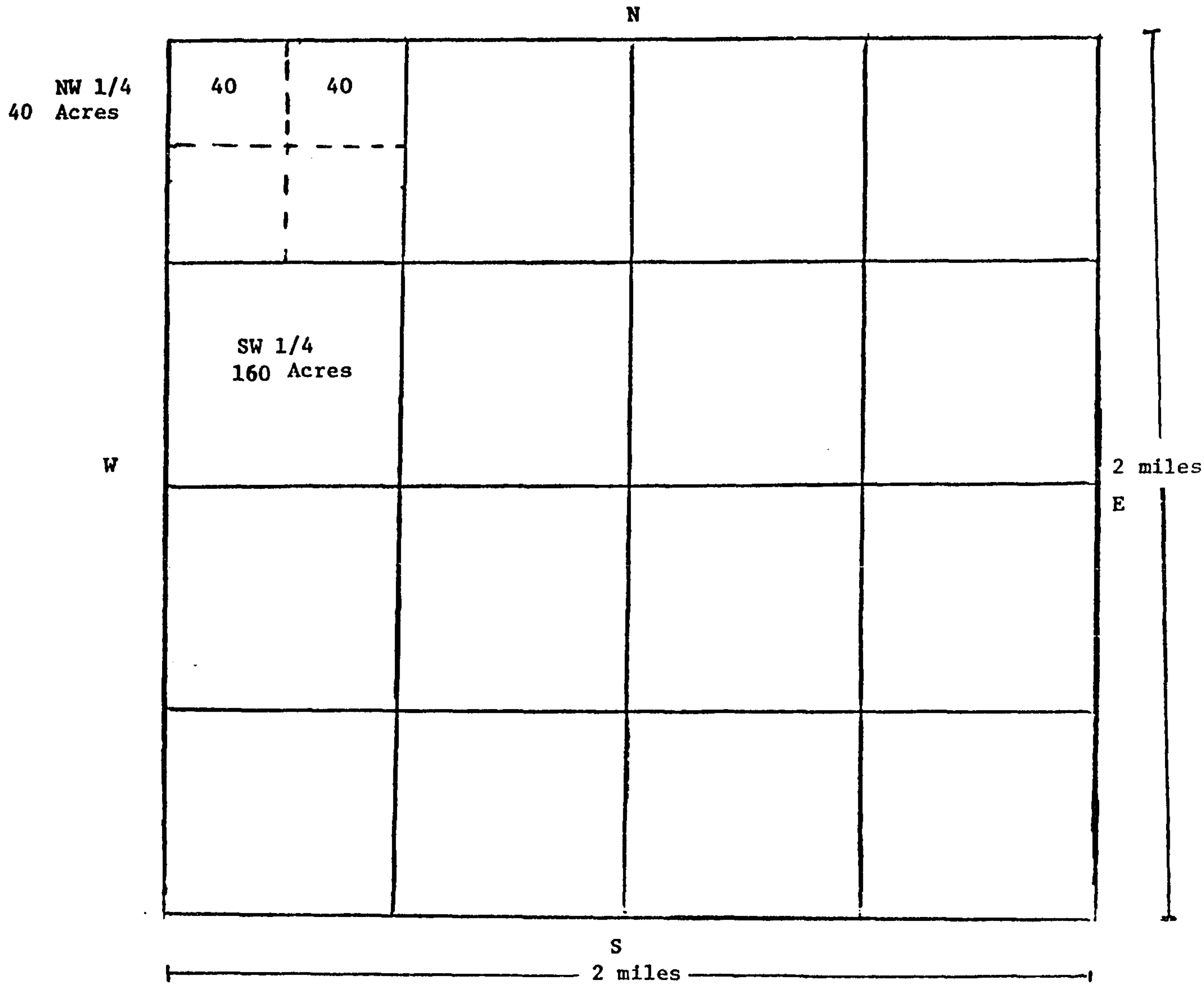
	Total	Owned	Rented	Soil Type
Tillable (cropland)	______	______	______	______
Diverted Tillable	______	______	______	______
Unoperated (Cropland)	______	______	______	______
Pasture	______	______	______	______
Woodland	______	______	______	______

Tillable acreage: Leased out____________

Value per acre: Owned____________Rented____________Rent Out____________

Pasture__________Woodland____________

Please indicate the location of each kind of land.*



*Refer to "plat book."

1. Tillable_______Acres. Diverted Tillable________Acres.
   Unoperated (cropland)________Acres. Pasture________Acres. Woodland______Acres.

2. What crops did you plant within a 2 miles square in 1973? (Acres)
   Corn________, soybeans________, Wheat______, Oats________, Barley________,
   Drybeans________, Alfalfa________, Others__________________________________
   ____.

II. Farm Labor Force

A. Family Labor Force (Man-Months on Farm)

Person	Age	Months	Days	Average Man-Month Equivalents
Operator				
Wife				
Son				
Daughter				
*Hired				
Total				
Labor for Livestock (subtract)				
Net Labor for Crops				

*Exclude labor furnished with hired machine custom work.

B. Labor supply during rush periods.

Maximum hours per week during rush periods.

Operator____________

Wife________________

Son_________________

Daughter____________

C. Hired Labor (Days Worked)

	December-March	April-May	June-July	August	September-November	Total for Year	
						Days	Wages
(a) Regular							
(b) Seasonal							

D. Off-Farm Work

(1)

	Kind	Wages/hour	Amount	Remark (when)
Operator				
Wife				
Son				
Daughter				

How many miles was your job from home?____________________

(2) If you have no off-farm work,

Have you tried to obtain off-farm work? Yes____No_____

What kind of work do you think you are qualified for

(1) without further training?_________, expected pay $_____/hour.

(2) with further training_____________, expected pay $_____/hour.

(3) why don't you work off-farm?_________________________

____

____

____

____

III. Machinery and Equipment (Inventory Beginning of Year) - January 1, 1972
*Value to farmers ≥ sale value and ≤ purchase cost, same quality

Item	Size	Model Year	Number	*Value
Major Equipment				
Tractor				
Combine				
Trucks				
Automobile (Farm Share)				
Tillage Equipment				
Plow				
Harrows (Spring & Spike Tooth				
Disks				
Cultivator				
Other				
Planting Equipment				
Grain Drill				
Seeder				
Corn Planter				
Sprayer				
Harvesting Equipment				
Hay Rake				
Bean Harvester				
Hay Loader				
Field Chopper				
Hay Baler				
Corn Picker				
Mower & Conditioner				
Elevator & Grain Augers				
Lime Spreader				
Grain Drying Equipment				
Other Major Equipment				
Wagons				
TOTAL CROP MACHINERY INVESTMENT				$

Purchase*				Sales & Trade ins			
Date	Item	Total Cost	Prop.Add.	Date	Item	Total Value	Prop. Ded.

*Includes tires and major overhauls and repairs reflected in ending inventory

Beginning Inventory $ ________

Prop. Add. $ ________

Prop. Ded. $ ________

Total Machinery Investment $ ________

IV. Gross Crop Income (1972)

Gross Crop Income Calculation------------------------------$ ________

Total Crop Income (P. 7)-----------------------------------$ ________

Crops, Feed & Seed Inventory Increase or Decrease (P. 8)--$ ________

Gross Income, excluding livestock--------------------------$ ________

IV. Gross Income (Continued)

A. Crop and Other Income

Crop	Acres	Yield/Acre	Unit	*Total Quantity	Quantity Sold	Date Sold	Unit Price	Value $
Corn for Grain			Bu.					
Soybeans			Bu.					
Wheat			Bu.					
Corn for Silage			Ton					
Oats			Bu.					
Barley			Bu.					
Potatoes			Bu.					
Dry Beans			Cwt.					
Sugar Beets			Ton					
Grass Silage			Ton					
Hay:								
Legume			Ton					
Grass			Ton					
Mixed			Ton					
Others								
Garden								
Land and Pasture Rent								
Custom Work or Machinery Rented								
Other Income from Farm Sources (Exclude Gov'nt Payment for Diverted Acreage)								
Total (Excluding Livestock)								

*Quantity includes sold and/or used for feed and food.

IV. Gross Income (Continued)

Inventories of Crops, Feed and Seed (January 1, 1972 - December 31, 1972).

Kind	Beginning Inventory		Ending Inventory	
	Quantity	Value($)	Quantity	Value($)
Corn				
Soybeans				
Wheat				
Oats				
Barley				
Dry Beans				
Others				
Silage				
Hay				
Commercial Feed				
Others				
Seeds				
TOTAL		$		$

Inventory Increase $______

Inventory Decrease $______

V. Fertilizer and Lime Cost

Crop	Amount Applied per acre	Total Quantity	Price	Cost
Corn				
Soybean				
Wheat				
Small Grains				
Others				

TOTAL $________

Residual Fertilizers & Lime: Only if very different in fertilizers and lime usage between 1972 and the normal year.

N, Total lbs.________x________% = ________x________¢ = $________
P_2O_5, Total lbs.________x________% = ________x________¢ = $________
K_2O, Total lbs.________x________% = ________x________¢ = $________

Total Residual. Value $________

Total Cost of fertilizer from which residual is computed $________
Minus residual value $________
Current fertilizer cost $________

Application Cost $________

Total Lime Cost (Annual Charge) $________

TOTAL FERTILIZER COST $________

VI.

Other Expenses

Item	Quantity	Cost ($)
Custom Work or Machinery Hired		
Fertilizer & Lime Cost (P. 9)		
Gas & Oil for Farm Use (Include fuel for Grain Dryer)		
Implement and Machinery Repairs (Not of an Investment Nature)		
Electricity (Farm Share)		
Automobile Operation (Farm Share)*		
Seed		
Herbicide (Weed Spray)		
Insecticides		
Other: (Baling Wire, Sacks, Crop Sprays & Pest Control, Telephone, etc.)		

TOTAL CROP EXPENSES $________

*Mileage x 10¢

VII.

Building Investment (Excludes Idle and That Used for Livestock).

Item and Description	Farmer's Estimate of Investment Value $
Granary	
Haystorage	
Corn Crib	
Silo	
Grain Bins	
Machinery Storage & Workshop	
Bucket Elevator	
Others	

Farmer's Estimate of total building Investment $________

VIII.
Capital Position

1. Do you have any additional funds and non-farm investments of your own which you could transfer to farm use to increase your investment in your farm business?

Yes__________No____________

If yes, what is the total amount? $__________________

2. Do you think you could borrow additional funds from any sources?

Yes_________No______________

If yes, how much?

	Amount	Rate of Interest	Duration	Restriction of Usage
Private Credit (Friend, relative, etc.)				
Chattel Mortgage (P.C.A.)				
Real Estate Mortgage (Bank)				
Land Contract				
Others				

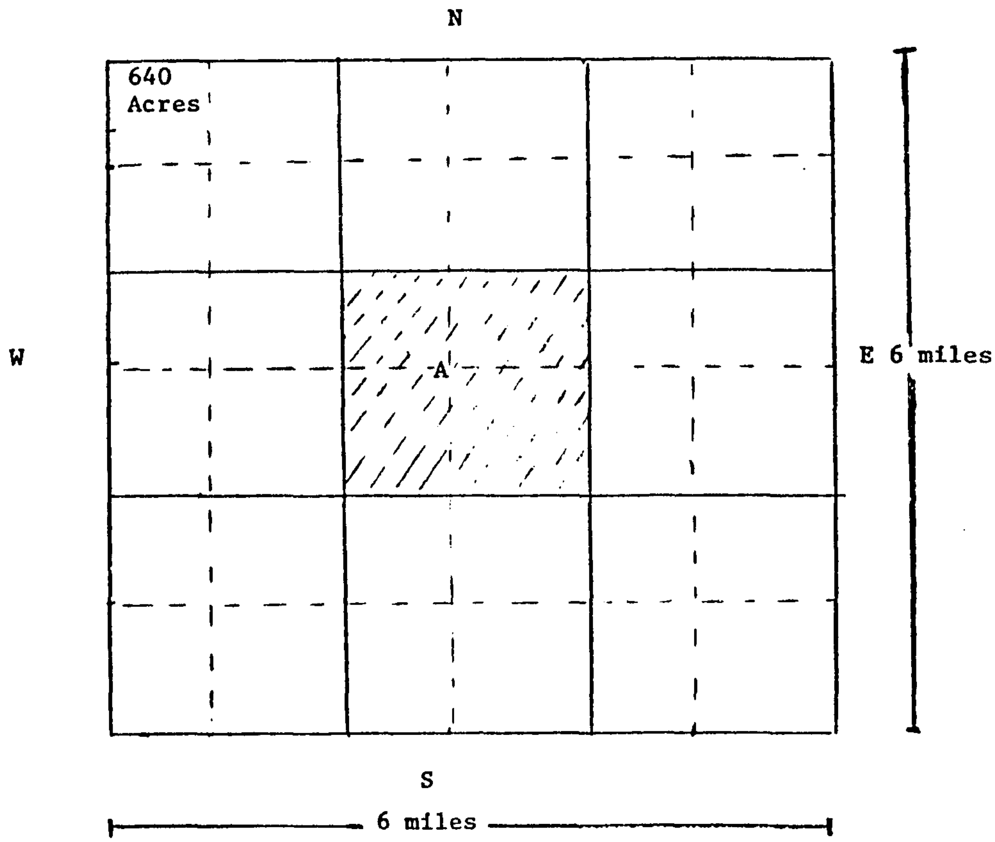
P.C.A.: Production Credit Association

3. List the possible "land <u>rental</u>" opportunities in your neighborhood for the next year.

Acres	Annual Rent	Kind of Contract (Cash or Crop Share)	Duration of Lease
1.			
2.			
3.			
4.			

Please indicate the location of land.*

Location



A: The 2 miles square area where visited farm is located.

*Indicate with blue ink, refer to plat book.

4. List the possible "land buys" which you know of in your neighborhood for the next year.*

Acres	Price per Acre	Contract Financing			
		Kind	Down Pymt.	Yrs.	% Interest
1.					
2.					
3.					
4.					

*Indicate the location of land on land map on Page 13, using red ink.

Land Utilization

1. After the termination of set-aside program next year, are you planning to produce more cash-grains if the prices remain at current level?

   Yes_______NO_________. If yes, how much ______________________________Acres.

2. What are the main reasons that you left a part of crop land uncultivated? (Number in order of importance.)
   Lack of Labor___________. Lack of Capital________________.

   Prices of output are too low or too uncertain______________.

   Cost of clearance is high____________________.

   Input prices are too high_________________unproductive (land)____________.

   Others____,

   Speculation___________, Lack of entrepreneur___________.

3. What factors are more important when you are solving the problem of pulling the idle land into production?

   Input prices_______, output prices_______, initial cost________,

   capital________, labor_______, entrepreneur_________.

4. Could you tell me the clearance cost (per acre) of your unoperated crop land?

	Clearance Cost			Drainage Cost ($)	Total
	Labor(hour)	Cash($)	Other		
(1) Diverted					
(2) Unoperated					
(3) Plowable Pasture					
(4) Woodland					

5. Do you have a plan to increase your production next year? Yes______No______.

Means / Kind of crops	More Intensive Cultivation	Bring in Diverted Land	Bring in Unoperated	Buy Land	Rent Land	Other
	Acres	Acres	Acres	Acre	Acre	Acre
Corn						
Wheat						
Soybean						

If No, please give the reasons.

6. What price expectation would be necessary to cause you to bring unoperated crop land into cultivation or buy or rent more land?

Expected Price of Crops

$/bu.

Corn________

Wheat________

Soybean______

Oats________

Drybean______

Net Worth Statement*

As of December 31, 1972.

Assets		Liabilities	
Land (p. 1)	$______	Farm Mortgage	$______
Buildings (on farm, p.11)	______	Other Mortgage	______
Machinery (Refer to p.5)	______	Bank Notes	______
Feed, Crops, Seed Supplies (p. 8)	______	Personal Notes	______
Livestock	______	Other Notes	______
Household Equipment	______	Accounts Payable	______
Stock, Bonds	______	Taxes, Rent, Insur. Due	______
Cash on Hand	______	Other Debts (household installment debts, etc)	______
Cash in Bank	______		______
Accounts Receivable	______		______
House	______		______
Other Assets (cars, etc)	______		______
	______	Total	______
	______	Net Worth	______
Total	$______	Total	$______

*We want estimates of the actual values, not the book values for accounting purposes. The point is, what were these items worth to you.

Farm No.____________
Tel. No.____________
Enumerator____________
Date____________

Confidential

Michigan State University
Department of Agricultural Economics
East Lansing, Michigan

Land Utilization Survey

I. Farm Size

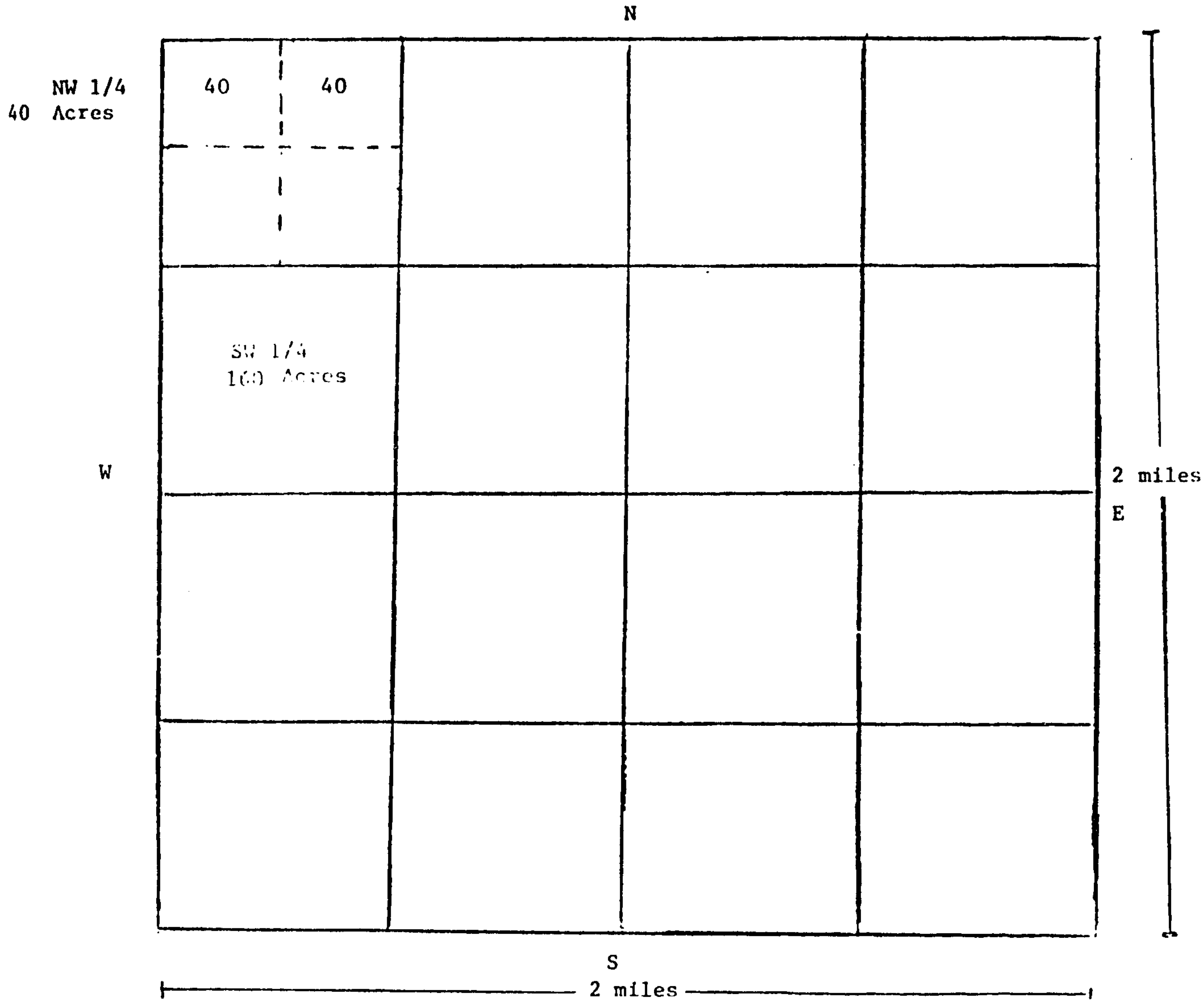
How many acres did you operate?____________

	Total	Owned	Rented	Soil Type
Tillable (cropland)	______	______	______	______
Diverted Tillable	______	______	______	______
Unoperated (Cropland)	______	______	______	______
Pasture	______	______	______	______
Woodland	______	______	______	______

Tillable acreage: Leased out____________

Value per acre: Owned____________Rented____________Rent Out____________

Please indicate the location of each kind of land.*



*Refer to "plat book."

Tillable_______Acres. Diverted Tillable________Acres.

Unoperated (cropland)________Acres. Pasture________Acres. Woodland______Acres.

Land Utilization

1. After the termination of set-aside program next year, are you planning to produce more cash-grains if the prices remain at current level?

   Yes__________No___________. If yes, how much ___________________________ Acres

2. What are the main reasons that you left a part of crop land uncultivated? (Number in order of importance.)
   Lack of Labor___________. Lack of Capital_______________.

   Prices of output are too low or too uncertain______________.

   Cost of clearance is high___________________.

   Input prices are too high_________________unproductive (land)____________.

   Others____,

   Speculation___________, Lack of entrepreneur___________.

3. What factors are more important when you are solving the problem of pulling the idle land into production?

   Input prices______, output prices______, initial cost________,

   capital_______, labor_______, entrepreneur_________.

4. Could you tell me the clearance cost (per acre) of your unoperated crop land?

	Clearance Cost			Drainage Cost($)	Total
	Labor(hour)	Cash($)	Other		
(1) Diverted					
(2) Unoperated					
(3) Plowable Pasture					
(4) Woodland					

5. Do you have a plan to increase your production next year? Yes______ No______.

Means / Kind of crops	More Intensive Cultivation	Bring in Diverted Land	Bring in Unoperated	Buy Land	Rent Land	Other
	Acres	Acres	Acres	Acre	Acre	Acre
Corn						
Wheat						
Soybean						

If No, please give the reasons.

6. What price expectation (next five years) would be necessary to cause you to bring unoperated crop land into cultivation or buy or rent more land?

Expected Price of Crops

$/bu.

Corn____________

Wheat____________

Soybean__________

Oats____________

Drybean__________

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