MARGINAL PRODUCTIVITIES OF INPUTS ON CASH CROP FARMS IN THE THUMB AND SAGINAW VALLEY AREA OF MICHIGAN, 1957

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by

M. David Brooke

AN ABSTRACT

Submitted to the College of Agriculture of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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ABSTRACT

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The purpose of this study was to estimate marginal value productivities for the various input, investment and expense categories of farm businesses. It was believed that such measures would provide a more objective basis for estimating efficiency of and making decisions on some of these inputs, particularly labor and machinery investment, than farm management research methods used in the past. It was anticipated the estimates, as a whole, would be valuable to farm managers, agricultural extension personnel, and representatives of lending institutions working in the area where the study was conducted.

The marginal value productivities were estimated by fitting a Cobb-Douglas function to the data collected from thirty, purposively sampled, cash crop farms in the Thumb and Saginaw Valley area of Michigan for the year 1957.

This function is of the form $Y = aX_2^{b_2}X_3^{b_3}\ldots X_n^{b_n}$ and is linear in the logarithms. The data were fitted by the method of least squares to the logarithmic form of the function in order to determine the regression coefficients (b_i's). The b_i's are estimates of the elasticities of the input categories with respect to gross income. The marginal value productivities, for the geometric mean organization of the farms surveyed, were then estimated from the equation $MVP_{X_i} = \frac{b_i\hat{Y}}{X_i}$, where $\hat{Y}$ is the antilog of the geometric mean estimated gross income and X_i is the geometric mean of the input category X_i in the prediction equation.

Five regression analyses of the data were made which included two assuming perfect complementarity among the input categories.

The input categories, their geometric mean quantities, regression coefficients and estimated marginal value productivities for the sample were:

	Input Category	Geometric Mean Quantity	Regression Coefficient	Marginal Value Product (dollars)
X_2	Land	193 T.A.	.224325	24.71
X_3	Labor	19 months	.275044	306.87
X_4	Machinery investment	$14,654	.204850	.297
X_5	Drainage investment	$19,135	.279131	.310
X_6	Current fertilizer and crop expenses	$ 6,609	.170704	.584

Note: These regression coefficients have been estimated from two different functions and thus the sum of these b_i's is not the true sum.

Geometric mean gross income was $21,252.

The estimated MVP's for land and drainage investment were computed from the b_i's obtained in the first Cobb-Douglas function analysis. The other MVP's were estimated from b_i's obtained in the final Cobb-Douglas function. This latter function assumed perfect complementarity of the inputs of land and drainage investment, which were set up as a combined limiting factor category. The MVP of this limiting factor was computed to be equivalent to $54.45 per drained tillable acre. (The average drainage investment per tillable acre was $99.90.)

Evidence of complementarity between the inputs was found, which might have been expected in view of the high intercorrelations of the input categories.

Tentative conclusions were that most of these farms were fairly well adjusted in 1957. Increasing returns to scale, indicated by the sum of the b_i's being persistently greater than one, suggested that proportionate increases in all inputs would be profitable, with some reservations. Land was a limiting factor on the smaller farms and raw land in general was yielding lower than expected returns, particularly in view of the high prices being paid for land in this area. Labor had a higher return than most other similar studies, particularly on livestock farms, have shown. The labor organization on these farms appeared to be efficient, but with opportunities for improvement by reducing labor requirements at sugar beet singling and hoeing time in particular. Large machinery investments have probably helped in the attainment of such high labor returns, nevertheless returns to investment in machinery were also good, being almost equated to marginal factor cost. Returns to drainage investment were high, emphasizing the importance of drainage on these farms. 1957 was a favorable year as regards this investment; even so, a further study of drainage may be worthwhile. Less confidence could be placed in the estimates of the returns to the other inputs of fertilizer and crop expense. They were showing a very low return which may in part be due to a less than normal response to fertilizer because of the weather in 1957. More attention to these items of expenditure could result in higher returns.

The use of these marginal value productivity estimates as a general advisory tool on individual farms was discussed and an example given. The conclusions were that although applications of this particular study were limited because the farms studied are so well adjusted, this method of analysis would be useful and highly desirable in areas of more poorly adjusted farms.

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

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CHAPTER I

INTRODUCTION

The British farmer is beginning to be faced with the labor problem which has plagued the American farmer for some time. Other industries are becoming more and more attractive to agricultural labor with the farmer being unable to pay comparable wage rates.

The substitution of machinery for labor which has taken place in the United States, together with the increased farm size is apparently part of the answer. Will it pay to do likewise in the United Kingdom? If so, how much does it pay? It is hoped that this study will illustrate a method of answering these questions.

Methods of farm management analysis commonly used in the U. K. measure labor efficiency in terms of productive work units per man. This is a measure of output per unit of input. In some instances, where large amounts of capital are used, a man may be accomplishing 500 days work per annum! It would therefore be an advantage to measure efficiency on a more objective basis. Continuous function analysis provides a method of isolating the return to each input category; thus if the profit motive is taken as the criterion, efficiency could be measured in terms of the income return per unit of labor.

Machinery use is obviously difficult to assess, with much subjective judgment involved. The possibility of measuring efficiency in terms of returns to investment appears attractive as it would provide some objective basis for assessing whether a farm was over or under capitalized with machinery.

It was decided that cash crop farming in the Saginaw Valley and Thumb area of Michigan should provide a useful and interesting study of a method for determining the marginal value productivities of inputs by subjecting the input-output data to a continuous function regression analysis. The theoretical basis for this procedure is discussed in the next chapter. The farms chosen were as purely cash crop as could be satisfactorily found. This was done in order to simplify the problem. It would have been useful to undertake the project on mixed farms but the accounting procedure necessary and the complexity of the problem, as pointed out by Beringer[1] and time limitations precluded the attempt.

The method of sampling and measuring the productive input categories is discussed in Chapter III. The fitting of the production functions and appraisal of the statistical results follow in Chapter IV. The evaluation of these results in Chapter V investigates the usefulness of the information in the area studied. Conclusions are drawn in Chapter VI with a discussion on the application of similar methods of studying farm businesses in the U. K.

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[1]Christoph Beringer, "Problems in Finding a Method to Estimate Marginal Value Productivities for Input and Investment Categories on Multiple Enterprise Farms." (Resource Productivity, Returns to Scale and Farm Size, Heady, Johnson and Hardin, Iowa State College Press, 1956. pp. 106-113.)

CHAPTER II

PRODUCTION FUNCTION ANALYSIS

The Optimum Allocation of Resources

It is assumed that the maximization of profits or returns to investments as a means to more ultimate ends is the underlying motive of farming. Marginal analysis enables the determination of the most profitable allocation of resources; this involves estimating the change in the value of total product brought about by the last unit of productive resource used. (The marginal value product or MVP.) It is economically profitable to continue adding units of a productive resource until the addition to total cost, or Marginal Factor Cost (MFC) is just covered by the marginal value product.

(1) $$MVP_{x_{1}(y)} = MFC_{x_1} \quad \text{or} \quad \frac{MVP_{x_{1}(y)}}{MFC_{x_1}} = 1$$

Where X_1 is one of the inputs producing the product Y with all other units of input $(X_2, X_3, \ldots X_n)$ remaining fixed.

As no one farm is generally capable of influencing either the price of the product or factor costs to his competitors perfect competition can be assumed. So that if P_y is the price per unit of output Y and P_{x_1} is the price per unit of input X_1, then for maximum profit

$$P_y \cdot \frac{MPP_{x_{1}(y)}}{P_{x_1}} = 1$$

The law of diminishing returns is assumed to apply to all inputs used singly and in various combinations on the farm. This assumption assures the existence of a high profit point. The law states that as inputs of a variable factor of production are added, in combination with fixed factors, the total product will first increase at an increasing rate, followed by a stage of increasing at a decreasing rate and finally the total product will decrease. This is illustrated in Figure 1a by the total value product curve (TVP).

The MVP curve is the slope of the TVP curve (or $\frac{dY}{dX_1}$). It pays to add X_1 as long as the output achieved covers the cost of the input; or until, at the point H, equation (1) holds. In this case, this is the optimum combination of X_1 with fixed inputs $X_2, X_3, \ldots, X_n$.

When two inputs are variable (X_1 and X_2) in combination with other fixed inputs the principle is better illustrated by a three dimensional diagram (Figure 1b), or a production surface. The iso value contours are the loci of combinations of the two variable inputs, with fixed inputs (X_3, X_4, ..., X_n), capable of producing a given amount of output, i.e., an equal elevation on the production surface. The inputs of X_1 and X_2 are shown measured along each axis. Output of Y is shown by the contours in the third dimension.

The iso cost lines are the loci of all positive quantities that can be purchased with a given outlay. The iso value product contour tangent to an iso cost line represents the greatest value of Y produced for that given cost of using inputs X_1 and X_2. This is the point of least cost combination for that output. The expansion path, or line of least cost combination (OA), is a line joining all these points of tangency at a given cost structure.

Figure 1b is intended to illustrate the law of diminishing returns so that a vertical section of the production surface along the line OA, or line of least cost combination, may look something like the TVP curve of Figure 1a. The X axis, in such a case, would then be designated by $X_1, X_2 \mid X_3, X_4, \ldots, X_n$.

Though diagrammatic illustration is impossible with more than two variable inputs, the concept still holds for any number. Assuming that all factors are not variable in the period under consideration, the law of diminishing returns will operate in respect of all the variable inputs combined in proportions dictated by the line of least cost combination. So that for maximum profit:

$$(2) \qquad \frac{MVP_{x_{1}(y)}}{MFC_{x_1}} = \frac{MVP_{x_{2}(y)}}{MVC_{x_2}} = \ldots = \frac{MVP_{x_{n}(y)}}{MFC_{x_n}}$$

If the MVPs of these variable inputs increase as all variable inputs are increased, the firm is experiencing increasing returns to scale, as a whole and with respect to each input. If the MVPs decrease as the variable inputs continue to increase the firm is experiencing decreasing returns to scale.

It continues to pay adding units of production as long as the resultant increment to total value product covers the increased

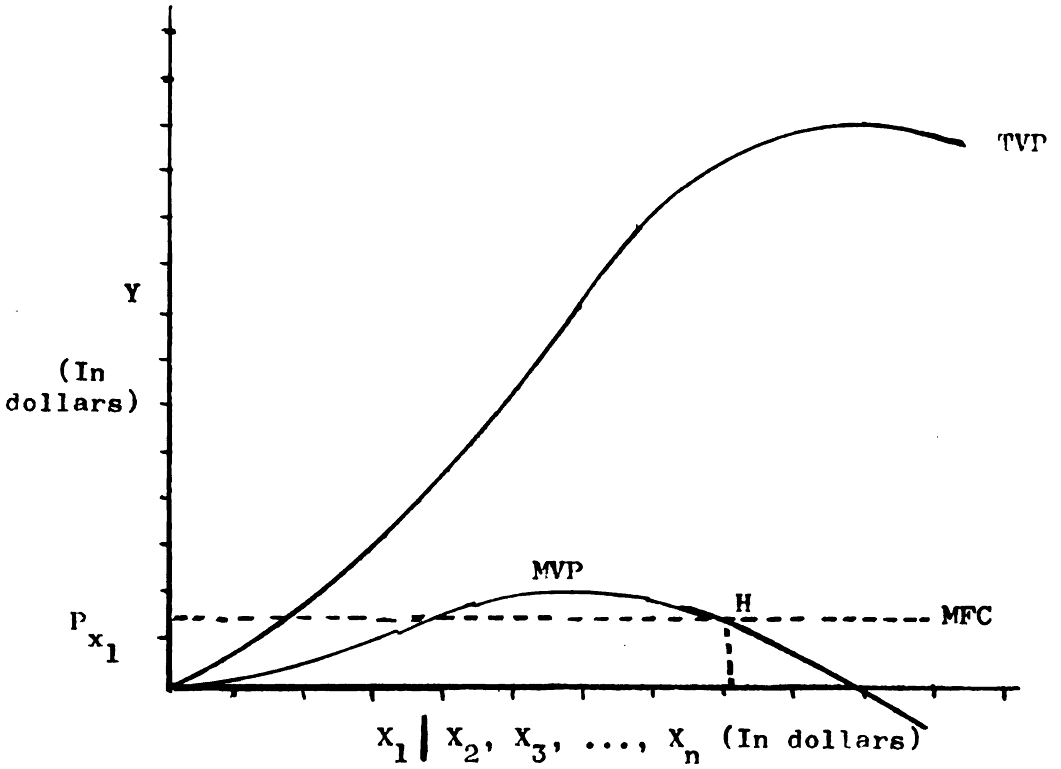

Figure 1a. Relationship between marginal value product, total value product and price of the variable input.

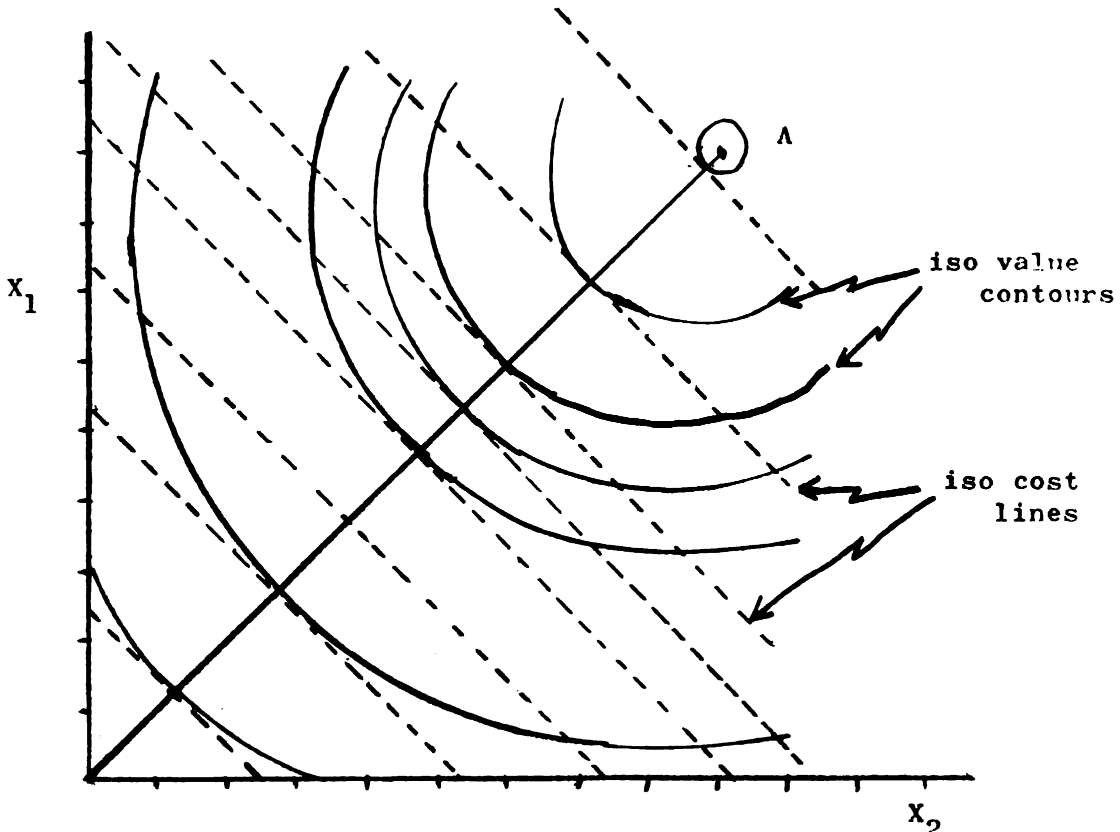

Figure 1b. Product contour map showing output dependent on two inputs with other inputs held constant.

cost of production, i.e., until equation (2) holds. If the marginal value product of one input exceeds that of another it pays to increase the use of that input before the other. For example, it may be found that the return to drainage investment (measured in dollars) is 20 percent, while the return to the investment in land (measured in acres) is \$30 per acre. The cost of undrained land is, say, \$400 per acre and assuming that a 5 percent return on land or drainage investment is necessary to cover interest on borrowed capital, maintenance, tax charges, etc., it would leave a net return on capital of 2½ percent for land and 15 percent for drainage investment. If this farmer had the choice of either buying more land, assuming normal capital restrictions, or completing the drainage of his existing land, it would pay him to do the latter until the conditions in equation (2) hold true. In practice, such decisions must necessarily be made more subjectively. The prestige value of a larger acreage may outweigh the difference in return to be expected from increasing the drainage rather than the land investment. This depends on the utility function of the individual manager. Also, such decisions must consider the future outlook of prices of land and farm products. Other risks and uncertainties involving weather and government policy may also be subjectively considered. The same is true of labor supplied by the farmer and his family which may have no established market price. Though such considerations are not currently ignored, it is suggested that a somewhat more objective basis would be of great assistance.

Grouping the Inputs

The principles outlined are applied to data from the farms surveyed in this research project. The inputs have been carefully grouped into independent categories (Chapter III) in terms of substitutability and complementarity. Classification is necessary in order to simplify reality. N variables, while theoretically solvable in a production function, make the task of determining the point of maximum profit extremely difficult.

Johnson suggests:[1]

(1) The inputs within a category should be as near perfect substitutes or complements as possible.

(2) Substitutes should be combined, as perfect substitutes are really one input which can be measured in terms of the least common denominator causing them to be good substitutes and priced in dollar value of the least common denominator. For example, the least common denominator of 5-10-10 and 6-12-12 fertilizer inputs would be units made up of equal amounts of N, P, and K, measured in terms of their dollar value.

(3) Complements should be combined, as perfect complements are really one input made up of the complements combined in constant proportions. They should be measured by counting the "sets" of such good complements in their proper proportions and priced on an index basis with constant weights assigned to each complement.

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[1] Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis (New York: John Wiley and Sons, Inc., 1953), p. 144.

Complementary examples are sets of machinery. Tractors, with their complements of cultivation and harvesting equipment can be counted assets or measured in dollar value. As the data collected apply to one year only, it is unnecessary to construct price indices.

These conditions, (1), (2) and (3), are desirable to ensure that inputs within each category are combined in proportions dictated by the scale line for a subproduction function treating the inputs in category as variable:

$$Y = f(X_1, X_2, \ldots, X_n)$$

(4) These input categories should be neither perfect complements or near substitutes relative to each other. This leaves the important economic questions involving input combinations to be answered by the analysis rather than covering them up within categories.

(5) Expenses and investments should be kept in separate categories, as the level of returns expected from these two types of inputs are quite different. Cash expenses, as annual inputs, are expected to yield at least a dollar per dollar spent. Investments cover a longer production period than a year; hence, annual return may be lower. Maintenance expenditures and depreciation should be eliminated from all input categories because of the difficulty in preventing duplication. Hence, expected returns to input categories of an investment nature should be high enough to cover interest, maintenance, taxes and depreciation.

All factors affecting the gross income cannot be adequately covered in a study such as this. Weather is uncontrollable and managerial ability, as an input, at the present state of knowledge, is immeasurable. Frank Knight[2] pointed out that our ability to make inferences depends on the existence of constant modes of behavior (with a known standard deviation from the mean). As the relevant variables are often too numerous for our limited finite human minds, it is necessary to classify them into a number of groups which exhibit similar behavior in certain respects. Even this simplification of the problem is insufficient as we cannot make an exhaustive classification and we have to fall back on consistency of behavior or theory of probability so that thinking can be ordered intelligently. Every effort was therefore made to classify the studied variables into homogeneous groups. The unstudied variables such as weather and managerial ability are assumed to have a normal and random distribution with respect to their effect on the dependent variable.

Fitting the Data to the Cobb-Douglas Function

The fitting of farm input-output data, in the categories developed, enables estimates of marginal value products to be determined. The function developed by Cobb and Douglas,[3] later revised by Douglas[4] is the type used in this study.

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[2]Frank H. Knight, Risk Uncertainty and Profit (Boston and New York: Houghton Mifflin Co., 1921), Chap. VII, pp. 197-232.

[3]Charles W. Cobb and Paul H. Douglas, "A Theory of Production," The American Economic Review, Supplement, XVIII (March 1928), pp. 139-165.

[4]Paul H. Douglas, "Are There Laws of Production?" The American Economic Review, XXXVIII, No. 1 (March 1948), pp. 1-41.

(3) $$Y = aX_1^{b1}\ X_2^{b2} \quad \ldots.X_n^{bn}$$

This is a cross product equation enabling the interdependencies of the variable inputs to be demonstrated. The function is mainly used to fit gross categories of inputs, as is required by this study. It is often found to be less useful in analyzing single inputs such as required in a soil and fertilizer or a feed and hog output study.

The function is linear in the logarithms and becomes:

(4) $$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + \ldots.b_n \log X_n$$

It is simple to fit to the data by least squares regression. In this study this was accomplished with an electronic computer. Once a fit has been obtained it is easy to manipulate and determine the marginal productivities.

The exponents (b_i 's) in the equation are the elasticities of the independent variables (X_i 's) with respect to the dependent variable (Y), in this case gross income. The value of these exponents indicates the percentage change in gross income associated with a one percent change in the respective input category, all other inputs held constant. The constant 'a' is the intercept with the Y axis. The marginal productivities of the input categories (X_i) may be calculated directly from the exponents by the formula:

(5) $$MVP_{x_i} = \frac{b_i\hat{Y}}{X_i}$$

where $\hat{Y}$, the estimated gross income, is the antilog of log Y in equation (4) and X_i is the quantity of the input under consideration (i = 1, ..., n).

Cobb and Douglas[5] originally imposed the restriction of forcing the sum of the exponents to equal one. This was equivalent to assuming constant returns to scale. Later this was relaxed and the sum of the exponents was not forced to equal one, permitting increasing, decreasing or constant returns to scale to be reflected.[6] If

$$\sum_{i=1}^{n} b_i < 1,$$

decreasing returns to scale are exhibited, if

$$\sum_{i=1}^{n} b_i > 1$$

increasing returns to scale are exhibited, and if

$$\sum_{i=1}^{n} b_i = 1$$

constant returns to scale are exhibited.

The estimated regression coefficients (b_i's) are constant over the entire function. This assumption means that the unmodified Cobb-Douglas function can only be used in certain cases where constant elasticity of the function can be presumed to exist. It also imposes the limitation of the inability to handle more than

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[5]Charles W. Cobb and Paul H. Douglas, op. cit.

[6]Paul H. Douglas, op. cit.

one stage of production for any given variable at a time (see Figure 2a). It was suggested that this may not be serious for the data under consideration, as it was believed that these farms were operating in stage II for all single input categories, i.e., where diminishing marginal returns are experienced. The optimum combination of resources can be achieved only in stage II for all variable inputs as a group. Though, strictly speaking, it is irrational to operate within the range of increasing or negative marginal returns, it was later found that the farms were operating in stage II for each input, but in stage I for total inputs.

The function is symmetrical (see Figure 2b), with iso product contour lines becoming asymptotic to the vertical and horizontal axes. This implies an unlimited range in which the proportions of two inputs can be varied to produce a given output. For example, in the labor machinery dimension, the form of the function indicates that a fixed amount of labor is capable of handling an unlimited quantity of machinery if one were willing to extrapolate beyond the range of any set of observable data. Such extrapolations, obviously, would be both impracticable and professionally dangerous. It is feasible that some production would be forthcoming with no investment in machinery, all the work being accomplished by hand. H. O. Carter[7] has suggested modifications to destroy the constant elasticity and symmetry aspects of the Cobb-

[7] H. O. Carter, "Modifications of the Cobb-Douglas Function to destroy constant elasticity and symmetry," Resource Productivity, Returns to Scale and Farm Size (Heady, Johnson and Hardin, Iowa State College Press, 1956), pp. 168-174.

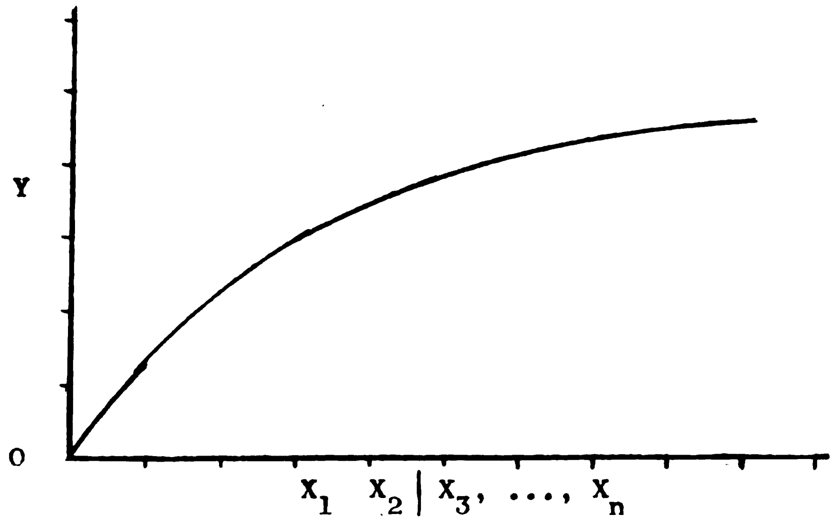

Figure 2a. The Cobb-Douglas production function illustrating decreasing returns to scale only.

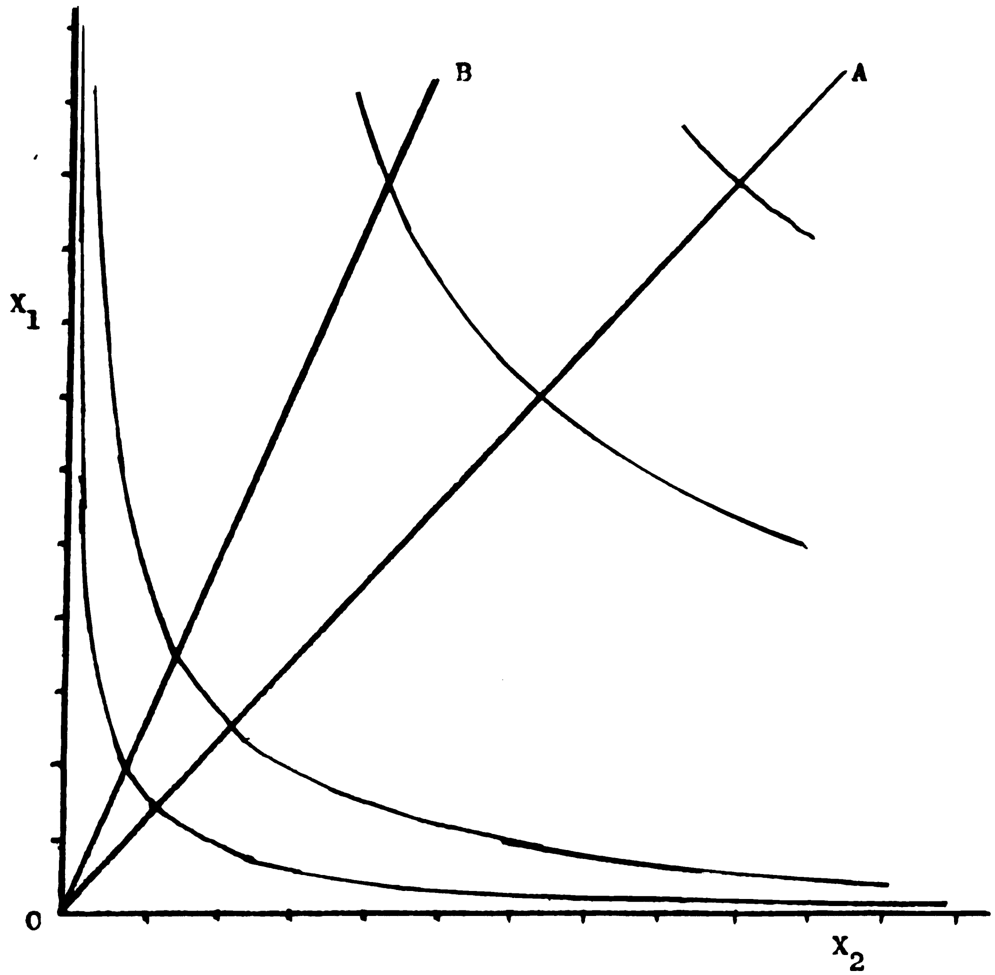

Figure 2b. The Cobb-Douglas production surface illustrating symmetrical asymptotic product contours, with straight line expansion paths.

Douglas function. The constant symmetry limitation dictates that any expansion path is a straight line cutting all iso product contour lines in the input dimension at the same angle, and passing through the origin. (See Figure 2b, with expansion paths OA and OB.) Again in the case of labor and machinery this may not be true. As machinery is added, the rate of substitution of machinery for labor would be expected to be quite high at first and then decrease, hence a curved expansion path could result.

However, the advantages of the Cobb-Douglas function with its ease of computation and simplicity outweigh its disadvantages for the purpose of this study. The assumption of constant elasticity of the regression coefficients and all that that implies must be kept in mind. The unexplained residuals must be assumed to be normally and randomly distributed with respect to the independent variables as the logarithmic transformation of the variable inputs presumes a substantial degree of normality of the distribution of the errors in the logarithmic data.

As already noted in the introduction, the continuous function analysis of a group of farms having widely different enterprises requires more time than available for this study.[8]

Purposive Sampling

The reliability of the estimates of the b_i's can be determined from the equation:[9]

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[8]Christoph Beringer, op. cit.

[9]Mordecai Ezekiel, Methods of Correlation Analysis, (Second Edition, New York: John Wiley and Sons Inc., 1949), p. 502.

$$\sigma b_{x_i} = \sqrt{\frac{\sum U^2}{N \sigma X_i^2 \left(1 - R^2_{X_{i(X_1 \ldots X_h,\ X_j \ldots X_n)}}\right)}}$$

Where:

$\sum U^2$ is the sum of the squared unexplained residuals. (Try to minimize to reduce σb_{x_i})

N is the sample number. (Try to maximize to reduce σb_{x_i})

σX_i is the variance of X_i. (Try to maximize to reduce σB_{x_i})

$R^2_{x_{i(X_1 \ldots X_h,\ X_j \ldots X_n)}}$ is the percentage of variance in X, explained by the other studied variables. (Try to minimize to reduce σb_{x_i})

Hence, it is necessary to obtain observations of the studied variables over as great an area as reasonable of the production surface; otherwise the estimations of the b_i's, and therefore the marginal value products, are liable to have a large error, unless a very large number of observations are made. Purposive sampling is designed to try to overcome this difficulty of reducing the number of observations necessary and to bring studies of this nature within the realm of economic possibility.[10] Farms are selected having wide quantity variations of the studied input categories with as little correlation as possible among these categories. This means that imperfectly adjusted farms with respect to the input categories should be included in the sample.

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[10] This is a question of weighing up the marginal utility or accuracy of the study with the marginal cost.

The unstudied variables, such as weather and managerial ability should be minimized as to number and variance with random and normal distribution with respect to the studied variables to prevent any bias in the estimation of the b_i's. Minimizing the unexplained residuals was accomplished by choosing a group of relatively homogeneous farms having the same inherent productive capacity, i.e., the same soil type with similar climatic conditions, this means limited geographic range. Variations are assumed to be randomly and normally distributed. In this study only purely cash crop farms, or as nearly pure as possible, were observed; livestock enterprises were carefully excluded from the data by avoiding such farms or by eliminating the livestock enterprise through accounting techniques.

All farms should be using the same range of technology and the same technology for a given combination of inputs. The quality of the inputs in each input category should be the same and they should be combined in the best possible proportions.

If the conditions in these last two paragraphs are successfully met, we can assume all these farms are operating on the same production surface and that the interfirm, intrafirm problem pointed out by Bronfenbrenner[11] does not apply.

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[11] Martin Bronfenbrenner, "Production Functions: Cobb-Douglas, Interfirm, Intrafirm," Econometrica XII, No. 1 (January 1944), pp. 35-44.

CHAPTER III

SAMPLING PROCEDURE AND MEASUREMENT TECHNIQUES

The Sample

Strong effort was made to select farms which were homogeneous with respect to the non-studied variables such as weather, type of production, technology and managerial ability, and which were non-homogeneous with respect to the proportions and quantities of the studied variables. This was in accordance with the reasoning in the previous chapter.

Table I gives detailed data for the individual farms in the sample.

(1) Type of farming was restricted to cash crop with the absence, or absolute minimum, of livestock. All these farms grew white pea beans, wheat and sugar beets, with some growing smaller acreages of oats, corn, barley, soybeans and alfalfa. Restricting the sample to farms growing sugar beets eliminated a large proportion of those growing cash crops. Otherwise the cropping is fairly representative for cash crop farming in the thumb area of Michigan.

The percentages of tillable crop land, by crops, in the sample was:

White pea beans	44.1%
Wheat	21.0%
Sugar beets	20.0%
Oats	5.2%
Corn	4.9%
Barley	2.7%
Soybeans	1.2%
Alfalfa	0.5%
Other	0.4%
	100.0%

TABLE I

SUMMARY OF EMPIRICAL DATA COLLECTED FROM THE THIRTY-ONE FARMS IN THE SAMPLE

Farm Number	Gross Income $	Tillable Acres	Labor Months	Machinery Investment $	Drainage Investment $	Fertilizer Expenditure $	Other Crop Expenses $	Machinery Storage Investment $	Grain & Corn Storage Investment $
1	20368	159	11.75	17235	20339	3798	2626	7630	910
2	19589	212	15.00	11750	12391	3001	3498	4840	400
3	53145	522	45.00	30410	35473	5140	6241	15390	1320
4	15210	214	19.50	10.47	12700	1972	4021	5500	1095
5	16510	138	14.00	10315	23951	2275	2592	7250	420
6	12093	93	11.00	9299	12761	1245	1428	8860	830
7	16594	76	11.75	6381	9578	1003	2877	2050	80
8	16066	179	11.00	12415	8949	2937	4142	8400	440
9	14047	106	12.00	8630	12510	1312	1849	6160	560
10	17591	178	16.00	10540	19538	2126	3635	5350	-
11	13731	131	15.00	13845	13800	1627	3050	6200	-
*12	9645	140	9.50	7760	950	1444	2093	2830	505
13	16709	203	11.50	21065	28678	2093	4772	8110	1070
14	17030	209	16.00	11545	13366	3715	3428	4550	1975
15	9054	79	10.75	7277	11661	1152	1643	1800	1108
16	26019	296	51.00	17795	21551	3587	3838	7630	510
17	12799	93	16.25	13045	10122	1428	4416	5200	1750
18	40201	324	29.00	29790	25772	3593	6567	8040	12750
19	52922	475	58.00	39300	30488	2552	7782	10700	1750
20	14799	146	12.75	11500	15730	1597	1711	5280	300
21	15933	115	12.75	12840	12429	2000	1735	4780	4250
22	12471	155	13.00	12765	13554	2241	3837	3750	2975
23	9349	112	12.00	4990	12688	1613	2488	3040	300
24	75878	617	64.00	30015	76702	5649	14348	10000	9200
25	14559	136	17.25	6255	12643	1869	3637	2710	200
26	48728	407	27.00	24150	47295	7489	7372	7250	5625
27	29232	286	25.25	19075	25109	2861	4585	5500	1200
28	18835	143	21.25	18010	16165	2653	3666	6790	400
29	58189	439	34.00	27025	50312	4590	8208	7500	2050
30	20919	146	22.00	17015	17620	6501	4748	5600	1700
31	62846	609	32.50	49090	66334	12677	9059	16130	16575

*Farm No. 12 was not characteristic of the sample, hence the data were omitted.

The percentage of land under a cover or green manure crop during the winter was 23.3 (sweet clover, alfalfa and clover or rye). This was usually plowed down for beans in late spring.

Livestock enterprises were absent from the majority of the farms. Some had a small flock of poultry. However, three or four farms fattened steers, for which most of the feed was bought. The income and expenses associated with these enterprises were fairly easily excluded from the data.

(2) All the farms were selected from the same soil type; the dark colored (Humic Gley) Lake Plain soils of the Saginaw Valley and Thumb area of Michigan. These are level, poorly drained soils formed from loams, silt loams and clay loams.[1] The principal soil types in the Saginaw Valley included Wisner and Essexville loams; these have a high pH which may result in minor element deficiencies, particularily manganese. The Prairie Farms, in the region south of Saginaw, are mainly on a Clyde clay loam which includes a mucky phase. On the farms selected no muck soil occurred. In the rest of the Thumb, the main soil types included Brookston, Kawkawlin and Conover loams. All these soils are relatively high in organic matter, nitrogen and lime. They are moisture retentive (all the farms selected required full tile drainage) and have good natural fertility. Differences in natural fertility were assumed to be randomly and normally distributed.

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[1]E. P. Whiteside, I. F. Schneider and R. L. Cook, Soils of Michigan, Special Bulletin 402, Soil Science Department, Agricultural Experiment Station, Michigan State University (January 1956).

One of the farms observed (No. 12) was on the fringe of this area and little drainage was required. The data from this farm were subsequently omitted from the analysis.

(3) The region from which the farms were selected (the "Bean Pot" of the United States) is fairly limited geographically. Differences in the weather had occurred throughout the region in 1957 and this had caused some differences in crop yields, particularly with the pea beans which are notoriously susceptible to excess moisture. It was believed that the differences that did occur were randomly and normally distributed.

(4) All the farms, as near as could be judged, were using technologies selected from a common bundle of available technologies; further, it appeared that farmers shifted technologies consistently as they substituted one input category for another. This is required in the assumptions of static production economics.

(5) The farms were using the same inputs, as defined later, in the input categories. These categories were designed to be as near perfect substitutes or complements of each other as possible, with the inputs within these categories combined in least cost proportions.

(6) It was assumed that all the farms were operating in the stage of decreasing returns to scale for individual inputs. The sum of the b_i's was later found to be slightly greater than one indicating increasing returns to scale when all inputs are considered; a situation which makes it impossible to estimate the most profitable size of farm to organize from the analysis presented herein.

The Data

"Purposive" sampling, as described in the previous chapter, was undertaken in an attempt to prevent high intercorrelations among the input categories. Farms were selected for visiting, after discussion with county agents and farmers, to insure they would be of the same type and that the sample contained as wide a range as possible of the quantities and proportions of inputs used in relation to other inputs.

Data were eventually obtained from thirty-one farms for the operating year 1957. The data from one farm was subsequently omitted, leaving thirty farms from which the continuous function analysis was run. The questionnaire used in personal interviews (see Appendix B) provided for the measurements of:

The dependent variable Y, or gross income.

The independent variables:

X_2 land, in tillable acres

X_3 labor, in months

X_4 machinery investment, in dollars

X_5 drainage investment, in dollars

X_6 current fertilizer expenses, in dollars

X_7 other current crop expenses, in dollars

X_8 machinery storage and workshop investment, in dollars

X_9 crop storage investment, in dollars

<u>Gross Income</u> (Y) was a measure of the actual production, from the tillable acres (X_2) for the year 1957. Income from

livestock was carefully excluded. However, any crop production in 1957 utilized by livestock (except grazing) was credited as gross income. Custom work and machinery rent were also included in gross income as it would have been almost impossible to separate the costs and investments involved from that of normal crop production; in any case, this represented a return to labor, machinery investment and machinery expenses.

There was no produce consumed in the house or other income from crop sources to be credited to gross income.

Six of the farms were growing a proportion of their crops for certified seed. In these cases the actual quantity produced was multiplied by the unit price which would have been obtained in the normal market. The excess costs and investments of producing seed instead of an ordinary cash crop were then carefully excluded from the input data. This method was a little unfair to those farms which grew barley and oats for seed; this acreage would otherwise have been in a higher value crop such as beans or sugar beets.

It was found unnecessary to make estimates of beginning valuations of crops on hand. Actual sales of the 1957 crop were taken and additions made for that part of the crop still unsold. The value of the crop still in storage was estimated on the basis of the reasonably expected price per unit, less storage charges, etc. The sugar beet crop is paid for in three separate installments, the final payment for the 1957 crop being in September or October 1958. Hence, the tonnage of sugar beets produced on the farm in 1957 was multiplied by $13.50 to obtain the gross income. This was estimated as being the most probable final total price.

In the case of share-renting, total production (including the landlord's share) was credited to gross income. If the landlord provided any input, such as a proportion of the seed and fertilizer, this was noted and included in the appropriate input category. No charge to expenses was made in the case of cash rent, instead the land rented was included in tillable acres.

Income from government payments in respect of land in the soil bank was excluded and such acreages and connected expenses were excluded from the corresponding input categories.

<u>Land</u> (X_2) was measured in actual tillable acres whether owned or rented with no allowances for roadways, ditches, farm buildings, etc. Any acreage leased out was excluded.

<u>Labor</u> (X_3) was measured in average man month equivalents spent working on the farm in respect of cash crop production including machinery maintenance, crop storage, crop handling and custom work. Labor used in connection with livestock was excluded. Time spent living on the farm by the operator and his family during the winter months when no productive cash crop work was being undertaken was excluded. In some cases operators were in the habit of taking off-farm jobs during the winter in, for example, the automobile industry. However, the recession during the winter of 1957 prevented many from obtaining such work. Others, who were more fortunate, took a long vacation (perhaps in Florida).

The few farms employing labor full time were charged with twelve months of work per man employed full time.

Seasonal work was usually in the nature of extra help at harvest time. Frequently extra trucks were hired for hauling the sugar beets. In such cases, $1.00 per hired truck driver per hour worked was deducted from the bill for haulage. This labor was then converted to man-month equivalents and credited as labor input. On many farms outside help and machinery hire for harvest were reciprocated in kind. The balance was credited or debited to the farm gross income or variable input categories. Mexican labor was generally employed for sugar beet thinning and hoeing and also for bean hoeing. In one case, sugar beet harvesting was undertaken with Mexican labor rather than hiring a mechanical harvester. Mexican Nationals were paid by the hour (85¢), in these cases it was relatively easy to determine the number of eight hour days worked. This was then converted to man months on the basis of twenty-five work days per month. The Texas Mexicans were usually paid on a flat acreage basis of $18 - $20 per acre for complete beet hoeing. In this case the number of actual man months worked was computed in discussion with the farmer.[2] Other farmers employed families of Mexicans.

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[2]The charge for sugar beet hoeing by Mexican labor was deducted from the sugar beet check by the Sugar Beet Company. A further deduction was made for rent in respect of housing for the Mexicans. The Sugar Beet Company usually owned these houses; however, in some cases the farmer was able to house the Mexicans in which case he was paid the rent. (This was not included as gross income.)

If family labor, e. g. children, was not capable of an average output of work they were credited with a reasonable proportion; similarly in the case of Mexican "family" labor.

Machinery and equipment investment (X_4) was a measure of the replacement value, in dollars, of the machinery and tools used in the workshop at the beginning of the 1957 season.

The major items of machinery -- tractors, crawlers, trucks, pickups, combines, bean harvesters, corn pickers and sugar beet harvesters -- accounted for 70-80 percent of the investment in machinery. Details were taken of these items as regards make, model, age and condition. Reference was then made to a guide to the value of used machinery[3] and local machinery agents. An objective replacement value was then placed on these items of equipment at early 1957 values, with a subjective account taken of their condition. Automobiles were similarly valued[4] but only that portion of the investment corresponding to the automobile operation charge (usually 50 percent) was credited as farm machinery expense.

The other items of machinery were valued at what the particular farmer thought they were worth in early 1957, i.e., what he could have sold them for, or what he could have bought them for in similar conditions.

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[3] Official Tractor and Farm Equipment Guide (January-June 1957). Compiled by the National Retail Farm Equipment Association. Published by Farm Equipment Retailing Incorporated, 2340 Hampton, St. Louis 10, Missouri.

[4] Official Used Car Guide (January 1957). Published monthly by the National Automobile Dealers Used Car Guide Co., 200 S. 7th St., St. Louis 2, Missouri.

Items of machinery dealing specifically with livestock enterprises were excluded.

In the few cases where machinery was purchased and sold during the operating season, proportionate investment charges were made according to the operating time for the 1957 season.

<u>Drainage investment</u> (X_5) was also measured in terms of January 1957 replacement cost. Only those drainage systems which were working efficiently were included; if any cases of the old 2" tile systems had been met they would have been ignored.

All the land on the farms in this study required tile drainage with the one exception, already noted. The land seemed best drained when the tiles were at intervals of 4 rods or less.

Records were made of the length of run, in rods, of each size of tile and the type of tile (clay or concrete). Similarly those ditches representing a farm investment were recorded in length of run in rods with average depth and bottom measurements. County ditches were not included. Rented or share cropped land was treated similarly.

The replacement value was calculated as follows:[5]

(1) Tile:

Trench digging and tile placement for 4"-8" tile was charged at $1.00 per rod plus 12¢ per rod for back filling, a total of $1.12 per rod. In the case

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[5]Based on figures provided by Willard A. Cutler, Assistant Professor, Ext. Agricultural Engineering, Michigan State University.

of 10"-12" tile similar costs were \$1.20 and 12¢ per rod respectively, a total of \$1.32 per rod. Replacement costs were then computed from the following table:

Tile		\$ Cost per 100 Ft. of Tile	\$ Cost per Rod of Tile	\$ Total Replacement Cost per Rod
Measurement	Type			
4"	clay	84	1.38	2.50
4"	concrete	77	1.28	2.40
5"	clay	132	2.18	3.50
5"	concrete	110	1.82	2.94
6"	clay	170	2.83	3.95
6"	concrete	150	2.50	3.62
8"	clay	260	4.33	5.45
8"	concrete	210	3.56	4.62
10"	clay	412	6.80	8.10
10"	concrete	380	6.27	7.60
12"	clay	540	8.91	10.25

(2) Ditches:

The estimated cost of spoil removal was 12¢ per cubic yard. A further 1¢ per cubic yard was required for spreading and leveling the soil giving a total of 13¢ per cubic yard.

Ditch Depth in Feet	$ Cost per Rod
4	3.18
5	4.57
6	6.20
7	8.06
8	10.17

The ditches were assumed to have a four-foot bottom and a 1½ : 1 slope.

Some farms had a much greater length of ditch than others, but as this was assumed to be in lieu of tile mains it seemed fair to include all these ditches as an investment charge.

Other items of drainage investment included costs of land leveling, culverts and special outlets. The investment in pumping and associated equipment was not included; so that the return to drainage investment, when calculated, will assume that if pumps are necessary they are already installed, otherwise they will be an "extra" item of drainage investment. In any case few farms in the Saginaw Valley and Thumb area have any large investment in pumps and high level carriers. The returns to drainage investment must also cover the maintenance charge for ditches, this was generally not very great ($2.00 - $4.00 per acre every fifteen or twenty years).

Annual or current fertilizer expense (X_6) included all fertilizer purchases which were applied to the land in the 1957 season. No lime was used on these farms as they rarely require it. If any difference in quantity of fertilizer used occurred between 1956 and 1957, it was noted. This was then used to compute the difference in residual fertilizers between the two years. If this balance was carried forward to 1958 the "excess" residual value was subtracted from the 1957 expense; or, if brought forward from 1956, the difference was added to the 1957 expense.

In computing the value of residual fertilizer it was assumed that 20 percent of all the nutrients (N, P and K) would be available the following year in the form they had been applied.[6] Residual P_2O_5 was valued at 9¢ lb., K_2O at 5¢ lb. and N at 15¢ lb. (1957 prices).

The fertilizer equivalent of animal residues applied to the land for the 1957 crop was also computed and credited as a current fertilizer expense. After discussion with members of the Department of Soils Science, Michigan State University and reference to pertinent literature,[7] the following table was adopted:

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[6] These estimates were made on the recommendations of L. S. Robertson, Assistant Professor of Soils Science, Department of Agriculture, Michigan State University. They take into account the soil type, crops grown on these farms, type of fertilizer used and the weather.

[7] L. M. Turk and A. G. Weidemann, Farm Manure, Extension Bulletin 300, Cooperative Extension Service, Michigan State College (June 1945). Table 1 (page 7) compiled from "Fertilizer and Crop Production," Van Slyke, Orange Judd Publishing Company.

Animal	Estimated Average Weight	1957 Fertilizer Values of Animal Residues, under Typical Conditions of Preservation	
		Average conditions; approx. 50 percent loss of plant nutrients	Better than average conditions; approx. 33.3 percent loss of plant nutrients
Steers	900 lbs.	$14.90	$20.00
Cows and calves	800 lbs.	13.25	18.00
Hogs	170 lbs.	2.75	3.75
Sheep (ewes and lambs)	150 lbs.	2.50	3.10
Poultry (per 100 birds)	400 lbs.	5.15	6.00

Similar values per pound of plant nutrient were taken as with the artificial fertilizers. The above figures thus apply to 1957 prices. The contribution of animal residues to soil fertility was generally small, but nevertheless not inconsiderable. In one case where a farmer fattened 160 steers annually, on a 140 acre farm, it was computed that this contributed the equivalent of $3,200 of artificial fertilizer.

The residual values of both artificial fertilizers and animal residues was only computed for the years of application; further residual values were ignored. Also, note, no direct account was made of the soil conditioning effect and other benefits contributed by animal residues.

Other current crop expenses (X_7) included power and machinery costs, seed costs and other items. (See Questionnaire in Appendix B.) These costs excluded machinery depreciation and also machinery maintenance charges, e.g. major overhauls and tire purchases, otherwise double accounting would have taken place in respect to the machinery investment category (X_4). The refund of State and Federal gas tax was deducted from the fuel and oil expense. Vehicle taxes and insurance were not included as these were not deemed productive expenses.

All seed used during the 1957 season was credited as an expense; this, therefore, included seed purchases and a charge for home grown seed.

Maintenance expenses to buildings were excluded and also all charges of an investment nature to land, e.g. land leveling, ditch filling and wood clearing. All interest, taxes and insurance charges were excluded.

If a difference in winter wheat acreage occurred between 1957 and 1958, the acreage difference was credited or debited to crop expense. The valuation of winter wheat was computed from quantity of fertilizer applied to the crop, seed cost of $5.00/acre (2 bushels of seed at an average cost of $2.50/bu.) and sowing costs of $2.60/acre. (Drilling at $1.40/acre plus discing and other cultivations at $1.20/acre.)[8]

Differences in beginning and ending acreages of green manure crops were also credited or debited as crop costs. These green manure crops were valued as follows:[9]

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[8]These figures were arrived at after discussion with farmers and M. H. Erdmann, Associate Professor, Ext. Farm Crops, Dept. of Agriculture, Michigan State University.

[9]These figures were arrived at after discussion with members of the Department of Soil Science, Michigan State University and reference to:

Type of Seeding	Quality of Stand		
	Poor	Average	Good
Catch crop: Sweet clover	$4.00	$ 7.50	$ 9.00
Catch crop: Alfalfa	4.00	8.50	10.00
Catch crop: Rye		4.00	
1-2 year alfalfa		16.00	

<u>The machinery storage and workshop investment</u> (X_8) was arrived at by making notes of the types of buildings with their respective floor space measured in square feet. The workshop represented building investment only. The replacement value was then computed from:[10]

Frame building without concrete floor	$1.50/sq. ft.
Frame building with concrete floor	1.75/sq. ft.
Pole barn building without concrete floor	1.15/sq. ft.
Pole barn building with concrete floor	1.35/sq. ft.

(1) J. R. Guttay, R. L. Cook and A. E. Erickson, "The Effect of Green and Stable Manure on the Yield of Crops and on the Physical Condition of Tappan-Parkhill Loam Soil," <u>Soil Science Society of America Proceedings</u>, Vol. 20, No. 4, Oct. 1956, pp. 526-528.
(2) L. S. Robertson, R. L. Cook, P. J. Rood and L. M. Turk, "Ten Years Results from the Ferden Rotation and Crop Sequence Experiments," <u>Michigan Agricultural Experimental Station Journal</u>, Article No. 1331.
The values of the green manure crops are in terms of response of pea beans (priced at $6.40/cwt.), as this was the usual crop to follow.

[10]These replacement costs were estimated in discussion with R. L. Maddex, Assistant Professor, Ext. Agricultural Engineering, Michigan State University, and reference to:
(1) <u>Current Costs of New Farm Buildings</u>, James S. Boyd, Professor, Dept. of Agricultural Engineering, Michigan State University. Paper presented at the Rural Appraisers Conference, Grand Rapids, Michigan, Sept. 12, 1957.

The pole barn type of construction was presumed to be the nearest approach to the replacement value of the old traditional wooden barn that was being used for machinery storage.

Crop storage investment (X_9) was estimated in a similar method to machinery storage. Notes were taken of the type of storage with capacity measured in bushels. The buildings were then valued on the basis of:[11]

(1) Grain or bean storage:

a) Round metal bins	35¢/bu.
b) Outside concrete bins	50¢ "
c) Old wooden bins in existing buildings	20¢ "
d) Wooden frame bins in existing buildings	35¢ "
e) Concrete bins + building + grain handling equipment	75¢ "
f) Wooden frame bins + building + grain handling equipment	85¢ "

(2) Corn storage (shelled corn equivalent):

a) Round wire, or cheap pole crib	30¢ "
b) Cheap "home made" crib	15¢ "

It is realized that this method of estimating the value of buildings in terms of replacement values may tend to overestimate the "real"

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(2) Arthur H. Schultz, Building and Equipment Costs, Dept. of Agricultural Engineering, North Dakota Agricultural College.

[11] These replacement costs were obtained from similar sources as for the machinery storage and workshop investment (X_8).

value and thus under estimate the marginal value productivity or returns to building investment. The value of a fixed asset[12] is determined by the income it earns. There is no market price for existing farm buildings which reflect their value as an earning asset.

Correlation of Input Categories

Although much effort was made to reduce the intercorrelations among the input categories, they remained high. Land, in particular, was very highly correlated with other inputs.

The simple correlations, with the exception of buildings (X_8 and X_9), were found to be:

$r_{YX_2} = .9268$	$r_{YX_3} = .8670$	$r_{YX_4} = .8649$
$r_{X_2X_3} = .8505$	$r_{X_3X_4} = .7504$	$r_{X_4X_5} = .8061$
$r_{X_2X_4} = .8449$	$r_{X_3X_5} = .7465$	$r_{X_4X_6} = .7625$
$r_{X_2X_5} = .8641$	$r_{X_3X_6} = .6423$	$r_{X_4X_7} = .7646$
$r_{X_2X_6} = .8117$	$r_{X_3X_7} = .7973$	
$r_{X_2X_7} = .8533$		

$r_{YX_5} = .8901$	$r_{YX_6} = .7888$	$r_{YX_7} = .8501$
$r_{X_5X_6} = .7578$	$r_{X_6X_7} = .7383$	
$r_{X_5X_7} = .7653$		

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[12] Bradford and Johnson, op. cit., p. 133. Economically an asset is fixed in a production process if:

(1) There is a difference between the cost of acquiring more of it and what can be realized by that quantity in hand by utilizing it in another process or selling it.

(2) The earning power of an asset makes it worth less in its present use than the cost of acquiring more of it, and more than

Where:

Y is gross income in dollars; X_2 is tillable acres of land; X_3 is labor months; X_4 is machinery investment in dollars; X_5 is drainage investment in dollars; X_6 is current fertilizer expenditure in dollars; X_7 is other current crop expenses in dollars.

The intercorrelations of the two remaining input categories of building investment (X_8 and X_9) were not high.

This would suggest that the farms in this sample were uniformly adjusted as regards proportions of inputs used. In fact, it may be suspected that some of these inputs were almost perfect complements, e.g., land and drainage investment.

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its opportunity cost or salvage value.
i.e., an asset is fixed as long as it is not worth varying.

CHAPTER IV

FITTING THE PRODUCTION FUNCTIONS AND APPRAISAL OF THE STATISTICAL RESULTS

The data obtained from the farms were used as the basis for five regression analyses.

The first function was run with all the variable input categories described in the previous chapter. The figures were converted to logarithms and fitted to the Cobb-Douglas function by the method of least squares.

The second function simply omitted the two input categories of drainage and machinery storage investment in an attempt to obtain a better fit with greater confidence in the estimates of the regression coefficients.

The complementary nature of the input categories suggested the third simple function with one input category in terms of the limiting factor, expressed in natural numbers. This function, which also presumed linearity was found to be inappropriate as curvilinearity was exhibited. The fit was improved in the next function by expressing the data in logarithms.

The fifth, and final, Cobb-Douglas function made use of the knowledge gained from the previous functions. Land and drainage were expressed in terms of the limiting factor of either. The machinery investment and labors input categories remained while the fertilizers and crop expense categories were combined. The other input categories were omitted. The fit was considerably improved over the second function and greater confidence could be placed in the estimates of the regression coefficient.

The First Function

The data obtained from the farms in the categories of gross income and all the variable inputs described previously, expressed in logarithms, were fitted to a Cobb-Douglas production function. The resultant coefficients and associated standard errors were as follows:

Land	b_2	=	$.224325 \pm .184355$
Labor	b_3	=	$.268144 \pm .136333$
Machinery investment	b_4	=	$.131911 \pm .149213$
Drainage investment	b_5	=	$.279131 \pm .130859$
Current fertilizer expense	b_6	=	$.034962 \pm .114102$
Other current crop expenses	b_7	=	$.108955 \pm .140355$
Machinery storage investment	b_8	=	$.027582 \pm .121716$
Crop storage investment	b_9	=	$.007784 \pm .019189$

The sum of the regression coefficients (b_i's) was 1.082794 which indicated increasing returns to scale.

The multiple correlation coefficient (R) was computed to be .9608, which with a sample size of thirty, eight independent variables and one dependent variable would be expected to be this high in 5 percent of the cases in a similarly drawn sample from a universe with a true (R) of .90.[1] As extreme values were selected

[1] Mordecai Ezekiel, *op. cit.*

in the sample, (R) is higher than would be expected from a random sample of farms in the universe studied, but not necessarily different than for a similarly drawn sample from the same universe.

The coefficient of determination (R^2) was .923, which means that 92.3 percent of the variation in the logarithm of the estimated gross income (Y) was associated with the independent variables included in the analysis. The remaining 7.7 percent of the variance was likely associated with such factors as weather and managerial ability (see page 10).

Log α was computed to be 1.095816. The estimate of gross income (Y) was then computed as log Y by inserting log α , the estimated b_i's and the logs of the geometric means of the input categories in the prediction equation (equation 4, Chapter II). It was found that log Y = 4.327391 or that the geometric mean of the estimated gross income = $21,252.

The standard errors of estimate ($\bar{S}$) of the dependent variable (log Y) was .08387, i.e., under the conditions prevailing in 1957 for the sample and assuming random distribution, log Y would be expected to fall between 4.327391 $\pm$ .08387, for the geometric mean organization of the farms in 68.27 percent (one standard deviation) of the sample, or in natural numbers between $17,520 and $25,779. The standard errors of estimate widens as the quantities of the inputs are increased.

The marginal value products of geometric mean quantities of the inputs were then computed (Table II) from the equation:

$$MVP_{X_i} = \frac{b_i Y}{X_i}$$

TABLE II

THE MARGINAL VALUE PRODUCTIVITIES OF THE GEOMETRIC MEAN QUANTITIES OF INPUTS USED ON THIRTY CASH CROP FARMS IN THE SAGINAW VALLEY AND THUMB AREA OF MICHIGAN, 1957 (DERIVED FROM THE FIRST PRODUCTION FUNCTION)

	Input Category	Geometric Mean Quantity of Input	MVP (Dollars)
X_2	Land	193 tillable acres	24.71
X_3	Labor	19 months	299.47
X_4	Machinery investment	$13,441	.209
X_5	Drainage investment	$19,135	.310
X_6	Fertilizer expense	$2,647	.281
X_7	Other crop expense	$3,827	.605
X_8	Machinery storage investment	$5,917	.099
X_9	Crop storage investment	$668	.248

The reliability of these estimates of marginal value productivity is related to the level of significance of the regression coefficient. Examination of the standard errors of the b_i's and their respective t scores indicated they were significantly different from zero at the 5 percent level for drainage investment (b_5), 7 percent level for labor (b_3) and 24 percent level for land (b_2). The estimates of the b_i's for the other input categories were less reliable.

A better method of testing the regression coefficients for significance, than against the null hypothesis, is to compare them with the regression coefficients necessary to yield marginal value products equal to a set of minimum expected returns. On the basis of observation and discussion with farmers and farm management specialists[2] the following were drawn up as reasonable minimum expected returns or reservation prices:

Land: A) Undrained	$35.00 per tillable acre
B) Adequately drained	$55.00 per tillable acre
Labor	$225.00 per month
Machinery investment	30 percent
Drainage investment	10 percent
Current fertilizer expenditure	$1.06 per $1.00 of expense
Other current crop expenditure	$1.06 per $1.00 of expense
Machinery storage investment	13 percent
Crop storage investment	13 percent

The minimum expected return to land was based on a 4-5 percent interest charge, one percent for taxes and maintenance and 3-4 percent to cover the risk factor--a total of 10 percent--with land valued at $350 per acre when undrained and $550 per acre when drained. The minimum expected return to labor was based on a wage rate of $170-$200 a month obtained by the Mexican National and the higher wage rate obtained by local casual labor at the rush periods of harvesting and sowing. It was suggested that the marginal unit of labor was a cross between the last unit added (i.e., at harvest time) and the next unit to be subtracted (i.e., at singling and hoeing). The return to machinery investment must cover depreciation, interest on investment, taxes, maintenance and insurance. Similarly the return to drainage investment must cover the interest charge on investment, all maintenance charges for tiles and ditches,

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[2] Professors L. H. Brown, C. R. Hoglund and J. M. Neilson, Dept. of Agricultural Economics, Michigan State University.

depreciation and the risk factor. If necessary, it must also cover pumping charges, interest on investment in pumping equipment and high level carriers, plus a charge for their maintenance.

A return of a dollar plus interest per dollar spent on fertilizers and other current crop expenses was expected. The returns to buildings had to cover interest on investment (6 percent), depreciation (4 percent) and maintenance and insurance (3 percent).

The estimated minimum expected returns were substituted as marginal value productivities in the equation

$$MVP_{X_i} = \frac{b_i \hat{Y}}{X_i} .$$

These were then solved for the b_i's. Table III compares these b_i's with the estimated b_i's.

TABLE III

COMPARISON OF THE ESTIMATED b_i's AND THE b_i's NECESSARY TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, FIRST FUNCTION

b_i	Estimated b_i	Estimated b_i σ	b_i to Yield Minimum Returns	Difference
b_2	.224325	.184355	.326255	-.09193
b_3	.268144	.136333	.206819	.051325
b_4	.131911	.149213	.194790	-.065879
b_5	.279131	.130859	.094234	.186697
b_6	.034962	.114102	.140664	-.105702
b_7	.108955	.140355	.203378	-.094423
b_8	.027582	.127157	.037159	-.009577
b_9	.007784	.019189	.004194	.003590

The regression coefficients were compared by the means of a "t test."[3] These showed that the estimated b_i's were not significantly different from the b_i's necessary to yield minimum returns, except in the case of drainage investment which was different at the 20 percent level of significance.

The reliability of the estimated b_i's for fertilizer and crop expenses was low. This is the reason for the difference between these estimated b_i's and the b_i's necessary to yield minimum expected returns not being significant. The resultant estimated MVP's nevertheless appeared to be the most widely different from the expected, of the input categories under consideration. As some of this may be due to the high intercorrelations among the input categories, a system of errors may exist. This could mean that some of the MVP's of fertilizer and crop expenses were being picked up by other inputs. Thus the MVP's of land, machinery investment and drainage investment were possibly overestimated and those of fertilizer and crop expenses underestimated.

The bean crop suffered from the weather in 1957 so that a full response to fertilizer applied may not have been achieved, thus lowering the return to that input.

Little faith can be placed in the reliabilities of the marginal value productivities of building investment (X_8 and X_9), because

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[3] $t = \frac{\hat{b}_i - sb_i}{\sigma\hat{b}_i}$ where $\hat{b}_i$ is the estimated regression coefficient and sb_i is the regression coefficient to yield minimum expected returns. Dixon and Massey, Introduction to Statistical Analysis (McGraw-Hill Book Company, Inc., Second Edition 1957), p. 115.

of the high standard errors of their b_i's and also the difficulty of actually measuring the value of buildings. Wagley[4] attempted to measure building investment, or value, in terms of animal units. The resultant regression coefficient was negative and no MVP was computed as it was felt unlikely that increasing the quantity of buildings would actually decrease gross income. Most attempts to measure the investment in farm buildings in physical or monetary units have proved unproductive. No method (including the Cobb-Douglas method) of estimating returns to buildings investment is able to differentiate between the marginal value productivities of highly correlated independent variables unless the sample size is very large.

The unexplained residuals[5] were computed for each farm and plotted against estimated gross income to enable any larger than normal discrepancies to be discovered. The distribution appeared to be normal and random. Most of these can be attributed to influences outside the scope of this study such as weather and managerial ability.

The Second Function

Knowledge gained from the first function suggested that the lower than expected returns to land may have been due to overestimation

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[4] R. V. Wagley, "Marginal Productivities of Investments and Expenditures, Selected Ingham County Farms, 1952," (unpublished M. S. dissertation, Dept. of Agricultural Economics, Michigan State College, 1953), pp. 45-50.

[5] Actual gross income minus estimated gross income.

of the returns to drainage investment. This was particularly suspected in view of the high intercorrelation (.86) of these two inputs. Similarly the estimated returns to machinery investment were lower than expected. This input was highly correlated (.80) with machinery storage investment so that some of the estimated returns may have been reflected in overestimation of the returns to this latter category. Also, the b_i for machinery storage and workshop investment was extremely unreliable.

The input categories of drainage investment and machinery storage investment (X_8) were therefore omitted and a further Cobb-Douglas regression analysis run. It was suggested that land and drainage were good complements so that as land was now virtually combined with drainage investment the input category of land referred to tillable acres having an average drainage investment of $99.90 associated with them. The returns to the machinery investment category would now be expected to reflect some of the MVP of machinery storage. Thus the new machinery investment category is interpreted as having a normal complement of storage facilities. This amounted to about $440 in storage investment per $1000 of machinery storage.

The resultant b_i's and associated standard errors were:

Land	b_2	$.37202 \pm .17857$
Labor	b_3	$.27342 \pm .14346$
Machinery investment	b_4	$.21117 \pm .12513$
Current fertilizer expenses	b_5	$.06743 \pm .11907$

Other current crop expenses	b_6	.10987 $\pm$ .14018
Crop storage investment	b_7	.00752 $\pm$ .02001

The sum of the b_i's = 1.04143.

The log of the estimated geometric mean gross income (log $\hat{Y}$) was 4.32739, equivalent to $21,252.

The multiple correlation coefficient (R) = .9518.

The coefficient of determination (R^2) = .9059.

The standard error of estimate = .088624, i.e., the log $\hat{Y}$ would be expected to fall between 4.3279 $\pm$.088624 in 68.27 percent of the sample, or between $17,329 and $26,053.

The marginal value products were computed to be:

MVP_{X_2},	land	$ 40.97 per drained T. A.
MVP_{X_3},	labor	$305.38 per month
MVP_{X_4},	machinery investment	$ .3339 per invested dollar
MVP_{X_5},	current fertilizer expense	$ .543 per dollar spent
MVP_{X_6},	other current crop expense	$ .6101 per dollar spent
MVP_{X_7},	crop storage investment	$ .2393 per invested dollar

The reliability of most of the b_i's had been slightly improved, but not sufficiently to increase greatly the confidence in the estimates of the MVP's, except in the case of land. The estimated b_i for this new input category (X_2) of average drained land was now significant at the 5 percent level. The b_i for machinery investment, including its complement of storage and workshop facilities, was now significant at the 12 percent level.

The Third Function, Assuming Perfect Complementarity of the Inputs

The possibility that the wrong function was being fitted now suggested itself. Perhaps it was, in fact, a case of complementary inputs. The very high intercorrelations of the input categories (except building investment) supported this idea. If the inputs were perfect complements, and as such exhibited constant returns to scale, the assumptions of linear programming[6] should apply, whereby production is increased until the constraints of limiting resources are exhausted.

The arithmetic means of the input categories used in the first function were taken to be "standard units" of inputs and the optimum combination of these inputs was taken to be the proportions among the arithmetic mean quantities of the input categories of the sample. The actual quantity of each input used on each farm (except the building categories X_8 and X_9, which were assumed to be non-limiting factors) was divided by its respective "standard unit" to determine which was the limiting factor of production[7] and the

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[6]The assumptions of linear programming are:

i, The processes of production are independent, with no complementarity between products;

ii, Linear relationships exist, i.e., constant returns to scale;

iii, The units of input are continuous;

iv, A finite number of production processes and resources are available;

v, The quantity of an input required to produce the unit product and the net return per unit of output are fixed and known. Also the productivity of a resource is limited to the total quantity available.

[7]The limiting factors in the sample of thirty appeared to be randomly distributed among the input categories. They were:

quantity. A simple regression was then run between units of limiting factor, irrespective of which category, against gross income.

The regression coefficient was computed to be $43,045.90 with a standard error of $2677.60. The reliability was, therefore, high. α was -$3,919.

The correlation coefficient (r) was computed to be .949866, which would be expected to be this high in 5 percent of a similarly drawn sample if the true coefficient were as low as .91. The coefficient of determination (r^2) was .902. These support the hypothesis of complementarity among the inputs.

The standard error of estimate ($\bar{S}$) of the dependent variable ($\hat{Y}$) was $5794.4, i.e., the arithmetic mean of estimated gross income would be expected to fall between $19,919 and $31,508 in 68.27 percent of the sample.

Examination of the unexplained residuals when plotted against the quantity of limiting factor showed the unsuitability of a linear production function. A definite curve about the zero residual line resulted which again, indicates increasing returns to scale. This showed up still more clearly when units of limiting factor were plotted against gross income (Figure 3). This evidence of increasing returns to scale supplements that of the Cobb-Douglas analyses, for which the sum of the b_i's was persistently greater than one.

Land	5	Drainage investment	4
Labor	4	Fertilizer expense	8
Machinery investment	4	Other crop expenses	5

The Fourth Function, Assuming Perfect Complementarity of the Inputs

The evidence of increasing returns to scale, and lack of fit in the last linear regression fitted to gross income and units of limiting factors, suggested a better fit may be obtained by expressing the data in logarithms, i.e., as a one variable input Cobb-Douglas function. The results were:

$b = 1.049541$ $\sigma b = .079394$

$r = .928383$ $\sigma r = .070231$

$r^2 = .861895$

$\log \alpha = 4.56179$

$\log \hat{Y} = 4.3273 \pm .097322$

A much better fit was obtained.[8] The ability of this function to predict gross income for this sample was not significantly different from that of the next and final function. (Refer forward for a comparison of these two functions on pages 56 and 58.)

For this function, it is necessary to resort to a residual method for estimating average returns which approximate marginal returns for the "average organization" to the individual limiting factors from the results of this analysis. Thus the AVP or the MVP of the limiting factor for the average organization in ordinary units is:

$$\frac{\text{Estimated gross income from a standard unit of limiting factor} - \text{Charges for non-limiting factors}}{\text{The number of ordinary units in a standard unit of the limiting factor}}$$

[8]One farm (no. 19) appeared to have an extremely low limiting factor (fertilizer input) in relation to gross income achieved, and this was still affecting the fit. When the data from this farm were omitted the fit was improved still further. ($r^2 = .8912$)

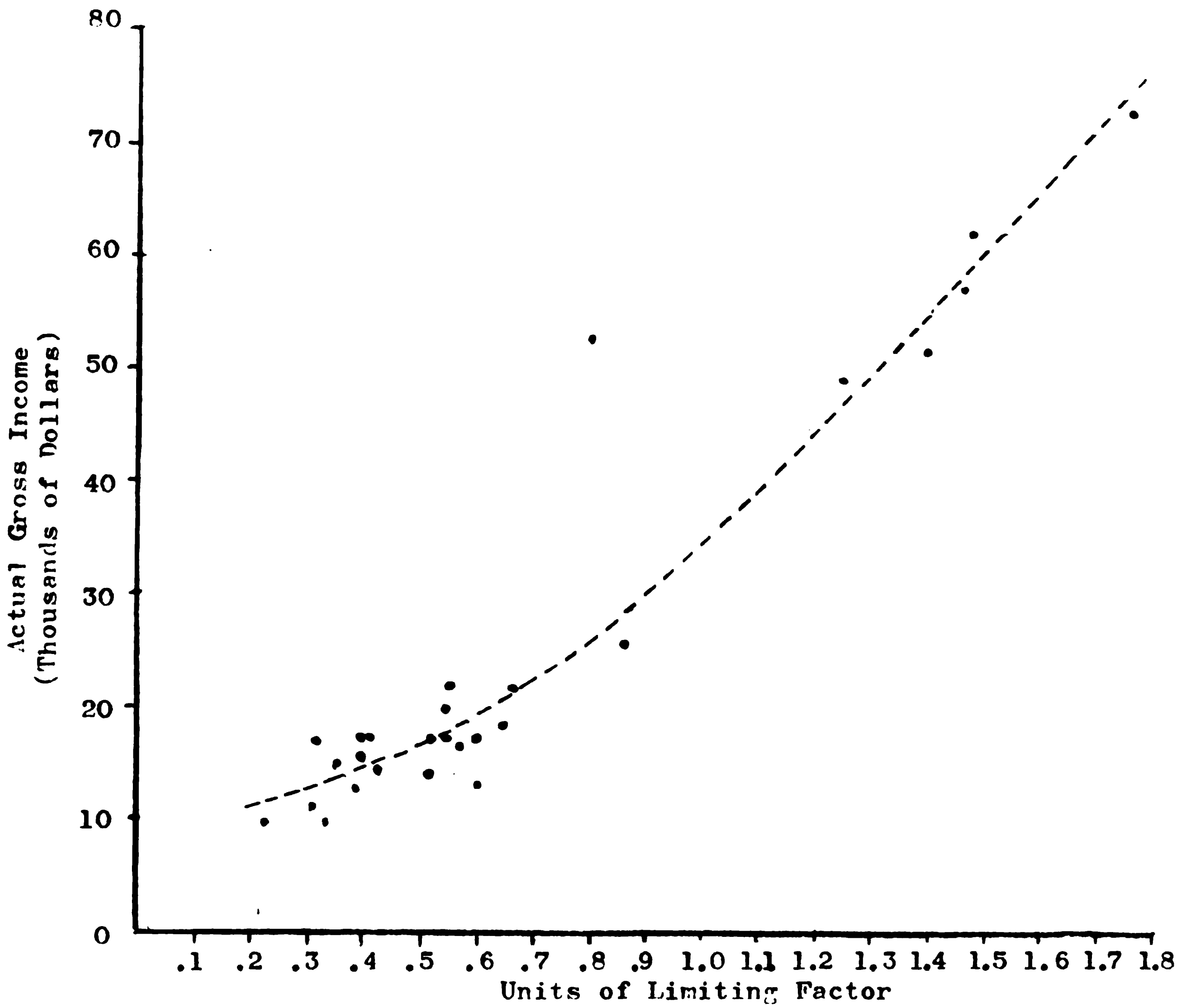

Figure 3. Relationship between gross income and units of limiting factor on the farms in the sample.

The standard units of the limiting factors, used in this analysis, with their respective expected returns, or minimum charges, are presented in Table IV.

TABLE IV

THE "STANDARD UNITS" OF THE LIMITING FACTORS USED IN THE FUNCTIONS ASSUMING PERFECT COMPLEMENTARITY OF THE INPUT CATEGORIES, WITH THEIR MINIMUM EXPECTED RETURNS

Input Category	"Standard Unit" of Input	Expected Returns[9]	Expected Returns or Minimum Charges per "Standard Unit" of Limiting Factors
Land	233.3 T.A.	$35/T.A.	$8,165.5
Labor	22.275 months	$225/month	$5,011.9
Machinery investment	$17,084	30 percent	$5,125.2
Drainage investment	$23,007	10 percent	$2,300.7
Fertilizer expenses	$3,210	106 percent	$3,402.6
Other crop expenses	$4,458	106 percent	$4,725.5

The estimating equation is $\log \hat{Y} = \log \alpha + b \log$ (units of limiting factor).

If the limiting factor is one, then log

$$\log \hat{Y} = 4.561792 + 1.049541 \times 0$$

or $$\log \hat{Y} = 4.561792$$

and $$\log \hat{Y} = \$36,457.$$

The productivity coefficients were then calculated to be:

Land	$68.11 per tillable acre
Labor	$571.83 per month
Machinery investment	.7522 per dollar

[9]Refer to p. 41.

Fertilizer expenses	3.4667 per dollar
Other crop expenses	2.7930 per dollar
Drainage investment	.4358 per dollar

These estimates are considerably higher than those determined from the normal Cobb-Douglas analyses due to the same excess return being credited to each estimated AVP or MVP in turn, i.e., if a mistake is made in estimating one, the same error will be reflected in each of the other estimates. Consistent under- or overestimation of the AVP's or MVP's by this residual method of computation can thus occur with all the estimates being biased in the same direction. This is a general characteristic of residual computation of AVP's and MVP's which can occur in farm accounting, linear programming and budgeting unless care is taken.

The unreliability of these estimated MVP's was one reason for fitting the next function even though the ability of the two functions to predict gross income was not significantly different.

The Final Function

It was now becoming apparent that land and drainage investment, in the area from which this sample was taken, were almost perfect complements. Hence, as with the regression analysis assuming perfect complementarity, the number of units of limiting factor of either land or drainage, measured in terms of the geometric mean quantities of either, was set up as one variable input (X_2). Labor (X_3) and machinery investment (X_4) were left as they were, as the MVP of these input categories are of particular interest to both farm management men and policy makers and it appeared that reliable estimates of their MVP's were obtainable. Current fertilizer and crop expenses were lumped together as one input (X_5), as it appeared that no headway was being made in obtaining a reliable regression coefficient for either alone. Crop storage investment was omitted because of the unreliability of the regression coefficient; hence, the return to the other inputs may, but do not necessarily, as the constant turned out to be slightly larger, reflect some of the returns to crop storage.

The estimated b_i's and their standard errors were found to be:

Units of limiting factor (either land or drainage investment)	b_2	.435713 ± .145849
Labor	b_3	.275044 ± .113725
Machinery investment	b_4	.204850 ± .123718
Current fertilizer and crop expenses	b_5	.170704 ± .136325

More reliance could now be placed on the estimates of the regression coefficients and hence also the resulting marginal value productivities. The estimated b_i's were now different from zero at levels of significance of one percent for the limiting factor (b_2), 3 percent for labor (b_3), 12 percent for machinery investment (b_4) and 23 percent for current fertilizer and crop expenses (b_5).

The sum of the b_i's was 1.08631, again indicating increasing returns to scale.

The marginal value products were then computed as in Table V.

TABLE V

THE MARGINAL VALUE PRODUCTIVITIES OF THE GEOMETRIC MEAN QUANTITIES OF INPUTS USED ON THIRTY CASH CROP FARMS IN THE SAGINAW VALLEY AND THUMB AREA OF MICHIGAN, 1957. (DERIVED FROM THE FINAL PRODUCTION FUNCTION, WHICH TREATED LAND AND DRAINAGE INVESTMENT AS PERFECT COMPLEMENTS)

Input Category	Geometric Mean Quantity of Input	MVP (dollars)
X_2 Limiting factor	.88038	10,507.05
X_2 in terms of drained land	193 T.A.	54.45
X_3 Labor	19 months	306.87
X_4 Machinery investment	$14,654	.2968
X_5 Current fertilizer and crop expenses	$6,609	.5484

As it was assumed that land and drainage were perfect complements, the MVP of limiting factor (X_2) now represents the marginal return to adequately drained land. This was recomputed to be $54.45 per drained tillable acre. It is of interest to note that the MVP for undrained land, from the first function fitted, was computed to be $24.71 per tillable acre. The returns to average drainage investment per tillable acre was computed to be $31.00, using an MVP for drainage investment of 31 percent. The sum of these two, representing total MVP of a drained tillable acre, is $55.71, which is almost the same as the $54.45 per drained tillable acre computed from this final function.

The log of the geometric mean gross income (log $\hat{Y}$) was 4.327391 with a standard error of estimate $\bar{S}$ of .078368, i.e., the geometric mean estimated gross income would be expected to fall between $17,743 and $25,454 in 68.27 percent of the sample.

Log α was 2.494105.

The multiple correlation coefficient (R) was .95919 which would be expected to be as high as this in 5 percent of the cases in a similarly drawn sample if the true (R) was .93.

The coefficient of determination (R^2) was .92.

The estimated marginal value productivity of current fertilizer and crop expenses still appeared low. As these inputs were highly correlated with other inputs some of the returns may still be reflected in overestimated MVP's of these other inputs. For instance it pays to apply more fertilizer to adequately drained land than undrained land as responses are less risky. Hence an overestimate in the MVP to drainage investment may result. In 1957 it is doubtful whether a normal response to fertilizer was in fact obtained. The bean crop in particular was adversely affected by the weather. As beans occupy 44 percent of the acreage of the sample this would mean a large reduction in response to fertilizer applications. Trials conducted by Michigan Agricultural Experiment Station on similar soils in 1957[10] showed economic responses in the cases of wheat and corn at low levels of fertilizer application only. Many of the farmers in the sample were using the accepted full fertilizing rates and hence it may be suspected that

[10] J. F. Davis, L. S. Robertson and W. B. Sundquist, unpublished results from "Fertilizer Input-Output Studies, 1957," conducted cooperatively by the Departments of Soil Science and Agricultural Economics, Michigan State University.

they were in fact not obtaining an economic response of at least a dollar per dollar expense at the margin.

The input categories of land, labor, machinery investment and drainage investment were quite highly correlated with the crop expenses category. Hence judgment must be used in interpreting the results. The MVP of machinery investment possibly also reflects some of the returns to fuel costs, which was a large item in the crop expense category. This could cause overestimation of the MVP of machinery investment with corresponding underestimation of the MVP of current crop and fertilizer expenses.

The estimated regression coefficients were compared with the regression coefficients necessary to yield minimum expected returns.[11] These are presented in the following table.

TABLE VI

COMPARISON OF THE ESTIMATED b_i's AND THE b_i's NECESSARY TO YIELD MINIMUM MARGINAL VALUE PRODUCTS, FINAL FUNCTION

b_i	Estimated b_i	Estimated b_i σ	b_i to Yield Minimum Returns	Difference
b_2	.435713	.145849	.457321	-.021608
b_3	.275044	.113725	.201666	.073378
b_4	.204850	.123718	.241579	-.036729
b_5	.170704	.136325	.342414	-.171710

[11] See p. 41.

The regression coefficients were almost identical in the case of drained land. Those for labor and machinery investment were not significantly different. However, the regression coefficient for current fertilizer and crop expense (b_5) was significantly different, probably due to the inclusion of the fertilizer expense in this input category.

The unexplained residuals were plotted against estimated gross income. The distribution appeared to be normal and random.

Complementarity of the Inputs

To test the hypothesis that the input categories, used in the limiting factor production functions, are better complements than can be fitted with a Cobb-Douglas function, a test was set up to compare the unexplained residuals of these functions with those of the first and final Cobb-Douglas functions.

The percentage of (the variance in Y minus the variance explained by the restrictions of the production function) explained by the analysis is given by:

$$R^2 = \frac{\sum u^2}{\sum (Y-\bar{Y})^2 \, \frac{n-m}{m}}$$

where: $\sum u^2$ is the sum of the squared unexplained residuals (Y-Y), Y is the actual gross income, $\bar{Y}$ is the mean, n is the number in the sample (30) and m is the number of restrictions (2 in the cases of the limiting factor functions, 9 for the first and 5 for the last Cobb-Douglas functions).

(a) First Cobb-Douglas function, R^2 = .799614

(b) Final Cobb-Douglas function, R^2 = .948745

(c) Limiting factor function in natural numbers, R^2 = .748333

(d) Limiting factor function in logarithms, R^2 = .8848.

It was then hypothesized that there was no difference between the R^2's. These percentages were tested by means of a chi square test.[12]

$R^2_{(c)\text{ and }(d)}\ \chi^2 = 1.737$, a difference significant at between the 10 percent and 25 percent levels.

$R^2_{(c)\text{ and }(b)}\ \chi^2 = 3.4607$, a difference significant at between the 5 percent and 10 percent levels.

$R^2_{(b)\text{ and }(d)}\ \chi^2 = .69206$, indicating no significant difference between these functions at between the 50 percent and 75 percent levels.

This means that the limiting factor function, expressed in logarithms (page 49) is not a significantly poor predictor of gross income than the Cobb-Douglas function. The advantage of the final Cobb-Douglas function is its ability to give reliable estimated MVP's as opposed to the unreliable residual method of computing them from the previous function.

Managerial Ability

The farmers in the sample were rated from 0-10 according to an informal assessment of their managerial ability made during

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[12] C. Eisenhart, M. W. Hastay and W. A. Wallis, Techniques of Statistical Analysis (First edition, McGraw-Hill Book Company, Inc., 1947), pp. 255-257, especially expression (16), page 257.

the interview. The profit motive was taken as the basis of the assessment but the farm records were ignored while the rating was being made. Assessments were made of their I.Q. together with their understanding, and use of, simple economic theory as applied to farming and their apparent ability to rationalize and come to decisions. This rating was then correlated with the percentage of estimated gross income actually achieved.[13]

First Cobb-Douglas function	r	=	.38318
	r^2	=	.14687
Final Cobb-Douglas function	r	=	.37660
	r^2	=	.14183

The correlations were low, but nevertheless significantly different from zero, fourteen percent of the variation in unexplained residuals being associated with this measure of managerial ability. The correlation has probably been reduced due to lowering gross income, by the accounting procedure, for farmers growing seed crops. These farmers generally were assessed as having above average managerial ability. Share renting was not common but may have been correlated with a lower managerial rating, thus affecting the correlation of gross income and managerial ability as yields on share rented land were generally lower than on owner occupied land.

If this is a reasonable assessment of managerial ability it would indicate that in this area difference in managerial ability

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$$\frac{\text{Actual gross income}}{\text{Estimated gross income}} \text{ or } \frac{Y}{\hat{Y}}$$

is not a major factor to be considered, i.e., management on these farms is a relatively simple matter or, of course, the level of management was relatively uniform and did not vary so greatly from farm to farm. The larger proportion of the unexplained residuals must be due to other unstudied variables such as weather, suggesting that these are more important factors than management. Weather can influence gross income quite considerably, particularly in relation to the bean crop.

CHAPTER V

EVALUATION

It must be stressed that these results apply only within the conditions of the study, the range of data collected and with the conditions of weather, price and state of knowledge existing in that area in 1957.

Land and Investment in Drainage

Land and investment in drainage are considered concurrently as their complementary nature has been demonstrated. This was particularly so in the final Cobb-Douglas regression analysis because of the reliability of the estimated regression coefficient from which the estimate of the marginal value productivity of drained land was obtained.

Farmers had good reason to be concerned with the high sale value of land, whether drained or undrained, in this area. Undrained land was estimated to be yielding less than expected returns and returns to drained land almost covered expected returns. It is probable that the drainage part of the investment in drained land, in 1957, was yielding a more than adequate return with under recoupment as regards the investment in the raw land.

Reference to Table X, in Appendix A, indicates that the marginal value productivity of land tends to fall as farm size increases. The proportion of land in the mix of the input categories tends to increase as farm size increases and this would result in the falling MVP for land. However, it does not fall rapidly, in fact the graph of gross income plotted against tillable acres is almost a straight line. The return to drainage investment appears to be similar irrespective of farm size.[1]

The importance of adequate drainage on these farms is obvious and this is supported by the estimated return of 30 percent on investment in 1957. Farmers estimate that a general increase in yield of 50 percent, or better, results from tile drainage.[2] 1957 was a favorable year as regards returns to drainage investment, so that a study should be extended over a number of years to obtain a more generally acceptable figure. It would be expected that the marginal return to 100 percent adequately drained farms would not be significantly different from minimum expected returns. If the estimated returns are much higher in average seasons it would indicate that it may pay farmers to tile drain their land at even closer intervals than the present accepted standard. As such a high return to drainage has been estimated from farms having on the average 80 percent of their tillable acres adequately drained, it suggests further investigation in this direction may be worthwhile.

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[1]The estimated returns to drainage investment are higher in the case of some of the 200-300 acre farms (see Table X, Appendix A). This is due to a lower percentage of the land being drained on these farms.

[2]C. R. Hoglund, Managerial Decisions in Organizing and Operating a Farm, Ag. Econ. Bull. No. 625, p. 6. Department of Agricultural Economics and the Agricultural Experiment Station, Michigan State University, September 28, 1955.

Labor

The estimate of the regression coefficient for labor in the final regression equation was highly reliable, but not significantly different from the regression coefficient required to yield minimum expected returns. Reference to Table VII shows that the resultant estimate of the MVP for labor was higher than those obtained in other studies, particularly those involving livestock. The reliability of the estimate of the b_i for labor in this study gives greater confidence to the MVP estimate for labor. It is not surprising that farms in this area are moving out of dairying and concentrating on cash crop production.

The total derivative to one month of labor was computed to be $1,297; this is the MVP of one month of labor in the geometric mean organization plus the sum of the MVP's of the increases in the other input categories associated with one month of labor. This result is higher than the average gross income per man month, in a report on this area,[3] of between $598 and $1,007 for 1957. This is largely due to (1) the method of measuring the input of labor, (2) the fact that the farms in the area report included a proportion of dairy farms which would have a lower gross income per man month than cash crop farms, and (3) increasing returns to scale.

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[3] Farming Today, Area 8 report, 1958. Cooperative Extension Service, Department of Agricultural Economics, Michigan State University.

TABLE VII

REGRESSION COEFFICIENTS AND MARGINAL VALUE PRODUCTIVITIES OF ONE MONTH OF LABOR, IN VARIOUS FARMING AREAS, OBTAINED IN RECENT STUDIES

	Study	b_i	σb_i	MVP (dollars)	Total Derivative to One Month of Labor (dollars)
1	Almont Township Michigan 1953	.160	.119	91.24	682.43
2	Burnside Township Michigan 1953	.186*	.096*	123.42*	816.19*
3	N W Illinois, 1950 (Hog enterprise)	.006	.084 per hour	8.40	1334.00
4	N W Illinois, 1950 (Dairy enterprise)	.222	.141 per hour	137.4	694.00
5	N W Illinois, 1950 (Crop enterprise)	.129	.166 per hour	143.6	1206.00
6	Ogemaw-Arenac Co., Mich. 1953 (Beef enterprise)	.382*	.301*	198.25*	660.03*
7	Ogemaw-Arenac Co., Mich. 1953 (Processed milk farms)	.414*	.154*	148.7*	428.90*
8	Ogemaw-Arenac Co., Mich. 1953 (Fluid milk farms)	.277	.113	123.96	594.61
9	Soil B. South Cen. Mich. 1953 (Dairy enterprise)	.076	.296	40.79	705.57
10	Soil P_4 Southern Mich. 1953 (Dairy enterprise)	-.034	.528	-21.43	599.91
11	Soil P. So. Cen. Mich. 1953 (Dairy enterprise)	.434	.237	262.08	798.43
12	Soil O. So. Cen. Mich. 1953 (Dairy enterprise)	.519	.299	304.9	797.26
13	Ingham Co., Mich. 1952 (Dairy enterprise)	.042	.130	30.19	787.01
	This study	.275	.124	306.87	1279.00

*Unreliable because of high intercorrelation with machinery investment.

The method of estimating labor input was a little more rigorous than most previous studies in that no account was taken of time spent on the farm between seasons. It was assumed that these operators then had the opportunity to take off the farm employment. This is usually available during the winter when average weekly earnings should be possible of \$86-87 per week or \$350 per month.[4] All family labor was reduced to average man month equivalents.

Even though returns to labor are relatively high, there is room for improvement. The most obvious being reduction in labor requirements for hoeing and singling sugar beets. The mechanical thinner was introduced into this area around 1950, at that time studies showed a 10 percent reduction in crop yield due to mechanical thinning which more than offset the 40 percent decrease in labor costs for hoeing.[5] Since then improvements in the thinners and techniques of using them have taken place and more recent studies[6] by the sugar beet companies in that area have not shown significant differences in yields due to mechanical thinning; on the contrary, frequently the yield has been improved

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[4] Michigan Labor Market, Vol. XII, No. 4 (April 1957), and Vol. XIII, No. 4 (April 1958). Published by Michigan Employment Security Commission, 7310 Woodward Avenue, Detroit 2, Michigan.

[5] George W. French, A Report on Tests of Mechanical Weeding and Thinning Equipment in Michigan and The Extent of Spring Mechanization in the Eastern Beet Area, 1951. Proceedings of the American Society of Sugar Beet Technologists, 1952, pp. 586-592.

[6] Monitor Sugar Beet Company, Mechanical Thinning of Sugar Beets, 1955. The Monitor Sugar Beet Co., Bay City, Michigan.

due to timeliness of the operation. These 1955 studies did not always show great reductions in labor requirements; however, it is generally suggested that a 50 percent reduction in labor requirements for thinning and hoeing the sugar beets would result.[7] Mexican labor used for hoeing costs farmers $170 to $200 per month, if they were obtaining a return of $306 for the marginal month of labor it would support their perseverance with hand labor. Other methods of reducing labor requirements during this period are now being investigated. The new approach is to obtain a more even stand of plants by using monogerm seed, better placement drills and obtaining ideal seed bed conditions.

Modern machinery and new techniques have reduced sowing time considerably. Unfortunately, this has resulted in all the sugar beets being ready for hoeing at the same time. In an area where custom labor is limited it is a case of "first come, first served." Hence, reduction of the total Mexican laborers force employed by the sugar beet companies in the Thumb area is not immediately likely. The shortening of the sugar beet thinning season could mean these Mexicans being partially unemployed between hoeings, in which case a higher wage rate for hoeing might be demanded. Mechanical thinning would then appear a more attractive proposition. It should also be noted that the mechanical thinner

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[7] C. R. Hoglund and K. T. Wright, Estimated Labor Requirements for Sugar Beet Productions in Michigan, 9.9 ton yield, Four Methods of Production. Adapted from Michigan Circular Bulletin 215, June 1949.

does enable a partial thinning of the stand at a critical stage when hand labor is not immediately available.

Other opportunities for improving labor efficiency would be at the later peak period of harvesting. Materials handling is a relatively recent field of study which may provide answers to this end of the problem.

The techniques of minimum tillage, which is now a recognized practice on these farms, have enabled substantial reductions in cultivation requirements so that farmers can now cope with what were once time consuming jobs. Modern machinery with its high work output has been of great assistance in this respect.

The MVP of labor tends to increase with increase in farm size. This might be expected from the evidence of increasing returns to scale, also as the number of tillable acres per man month tends to increase with farm size. It is interesting to note that these returns are significantly higher on the 130-150 acre, family size, holdings than the small, 70-100 acre holdings; but returns do not increase so rapidly on the larger farms. This might suggest that the 130-150 acre holding is a minimum size in order to employ fully the operator's and family labor, and provide adequate returns to that labor.

Few farmers employed full time labor. Those that did, provided some incentive to keep the workers on the farm. They were all provided with rent free housing and most of them had some opportunity to augment their income by cropping a few acres of their own accord, using their employer's machinery at a nominal charge.

Machinery

This area is very highly mechanized which has assisted in the reduction of labor requirements and led to an improvement in the returns to labor. Reference to Table VIII indicates some of the substitution of machinery for labor in this area during the past twenty years. It should be pointed out that more machinery and less labor were spread over a larger acreage, as the average farm size in the reports on this area,[8] from which Table VIII was derived, increased from 102 acres in 1935 to 149 acres in 1956.

The b_i for machinery investment is not significantly different from that necessary to yield minimum returns. However, the returns appear lower on the small farms suggesting their over-investment in machinery, or underinvestment in respect of land. Machinery investment per tillable acre decreases with increase in farm size. The opportunities on these small farms to reduce their investment in machinery are not as great as might first be thought. The real difficulty is that the bean crop needs immediate harvesting during a critical period; hence, the bean harvester or combine must be immediately available. As already pointed out, modern methods of sowing have resulted in most of the crop, in this area, being ready for harvesting at the same time, so that the neighbors' or the custom combine may not be available and the crop consequently lost. This position has not been improved by the persistent use of bean varieties which mature at the same time. Grain and sugar

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[8] Farming Today, Area 8 report, 1935-56, op. cit.

TABLE VIII

NUMBER OF MEN AND MACHINERY INVESTMENT PER 100 TILLABLE ACRES, 1935-1956, AREA 8, MICHIGAN[9]

Year	Number of Men	Deflated Machinery Investment 1937-41 = 100
1935	1.96	$1200
36	1.79	1212
37	1.73	1344
38	1.76	1563
39	1.65	1649
40	1.60	1716
41	1.52	1858
42	1.57	2042
43	1.36	2033
44	1.30	1936
45	1.33	2057
46	1.36	2050
47	1.34	1980
48	1.32	2053
49	1.37	2395
50	1.38	2691
51	1.33	2722
52	1.28	2914
53	1.23	2982
54	1.23	2991
55	1.11	2978
56	1.07	2930

beet harvest is spread over a longer period enabling outside assistance to be possible. An alternative is cooperative machine ownership. Only one real case of this was met on the farms visited. Here, four farms, each of about 120 acres, cooperatively owned a combine, a bean harvester and a sugar beet harvester. Generally, more friendships have been broken than made in cooperative ownership

[9]Area 8 is cash crop and dairy farming in the Saginaw Valley and Northern Thumb areas of Michigan.

of harvesting equipment. However, in this case, the success of the venture can be judged from a five year history of almost perfect harmony. The basis was a properly drawn up agreement whereby expenses were paid on a crop proportion basis and from a central fund raised by custom work with this machinery. Fuel and oil were provided by the farmer concerned and labor assistance was paid for on a regular hourly basis. In the case of beans, only twenty acres could be harvested at one time by any one farmer; each had to take his turn.

Many farms appeared to have more tractors than necessary. All farms had two tractors and some small farms even had three. The reason given for this was ease of operation. The idea was to have a large high horsepowered tractor for the heavy work of ploughing and preparing a seed bed, etc., and a light, more maneuverable tractor for row-crop work. This allowed the small tractor to be hitched up with inter-row cultivation equipment throughout the season, leaving the larger one free for other work and thus avoiding the time consuming job of attaching and unattaching equipment. The essence of farming in this area appeared to be to have the equipment to get the job done as quickly and as efficiently as possible because of the critical periods of crop sowing, growth and maturity. Pride of possession also seemed to be a factor, as many small farms had invested in overly large combines.

Fertilizer Expenditure

The estimated b_i for fertilizer expense had a high standard error which made the estimate of the MVP unreliable. Reasons have already been given for suspecting that returns to the fertilizer input were, in fact, less than a dollar for a dollar in 1957. Also, the MVP may be underestimated with corresponding overestimates in the MVP's of land and drainage investment. Nothing more will be added here, except that fertilizer input-output studies in this area[10] have indicated that more than a dollar return per dollar invested is obtained in average years with the generally accepted levels of fertilizer application. Table IX indicates the variation in quantities of fertilizers applied to the three main crops on the farms in the sample in 1957.

It appeared that wheat was most frequently over fertilized particularly with nitrogen and this was borne out by observations of the farmers concerned. The breeding of a short, stiff-strawed wheat for this area is urgently required. Many farmers were using more than optimum quantities of nitrogen on sugar beets.

Other Current Crop Expenses

The estimated b_i was unreliable reducing the confidence in the estimate of the MVP for other crop expenses. The estimates

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[10] L. S. Robertson and W. B. Sundquist, An Economic Analysis of Some Controlled Fertilizers Input-Output Experiments in Michigan. Data 1955 and 1956. Unpublished technical bulletin. Michigan Agricultural Experiment Station.

TABLE IX

RANGE IN QUANTITIES OF ARTIFICIAL FERTILIZERS APPLIED TO THE THREE MAIN CROPS OF THIRTY SAGINAW VALLEY AND THUMB CASH CROP FARMS IN 1957

Crop	Plant Nutrient	Pounds of Fertilizer Applied per Acre		
		Lowest Level	Highest Level	Suggested Optimum Rates[11]
Sugar Beets	N	20	130	40
	P_2O_5	72	234	80 - 160
	K_2O	72	376	40 - 80
Beans	N	0	12	15
	P_2O_5	0	48	30 - 60
	K_2O	0	48	15 - 30
Wheat	N	8	67	16
	P_2O_5	21	200	48 - 96
	K_2O	21	200	24 - 48

from this study suggest an inefficient use of this input in 1957, with the reservation that some of the return to fuel, in particular, may be reflected in overestimated returns to the machinery investment and labor input categories.

Buildings

Little confidence can be placed in the estimates of returns to crop storage and machinery storage investments. Other studies

[11] Fertilizer Recommendations for Michigan Crops, Extension Bulletin 159 (Revised), Oct. 1957. Michigan State University Cooperative Extension Service, p. 16.

which have attempted to estimate the regression coefficient of investment in buildings have met with the same difficulty of adequately measuring the value of buildings. No observation on the returns to building investment will therefore be made.

Increasing Returns to Scale

Since the sum of the b_i's was consistently greater than one, and also because of supporting evidence from examination of the data with inputs treated as perfect complements, increasing returns to scale are indicated. Increasing farm size and consequent reduction in the number of farms in this area cannot, therefore, be expected necessarily to reduce overall production.

Increasing returns to scale also means that it is impossible to compute a high profit point unless one or more of the input categories are held constant. In any case, extrapolation beyond the range of the data is not advisable. However, as suggested by Kaldor,[12] management may eventually prove the limiting factor; this important input, by necessity, was not included in the empirical production function.

The Complementarity of the Input Categories

The complementary nature of the input categories has been demonstrated, particularly in relation to the inputs of land and

[12] N. Kaldor, "The Equilibrium of the Firm," Economic Journal, Vol. 44 (1934), pp. 60 ff.

drainage investment as shown in the final function. Also, the function assuming perfect complementarity of the inputs, when expressed in logarithms, was not significantly different in its ability to predict gross income than the final function. However, the superiority of the final Cobb-Douglas function is in its ability to produce less biased estimates of the MVP's of the input categories.

The simple linear function assuming perfect complementary of the inputs did not provide a good fit as increasing returns to scale were exhibited. If the optimum proportions of inputs had been known and used to discover the limiting factors a better fit may have resulted. This suggests that a linear programming study in this area may prove interesting and worthwhile.

Reorganization of a Farm on the Basis of the Estimates

It has already been noted that the farms in the sample appeared to be fairly well adjusted to conditions existing in 1957. An attempt was made to discover maladjusted farms as this would have increased the reliability of the estimated regression coefficients. As this attempt, unfortunately, was not too successful, there are few farms in the sample which can profitably be investigated with a view to attaining a much better adjustment. However, one farm (No. 16) was sufficiently out of adjustment to warrant examination and can be used to illustrate the use of this type of analysis for individual farm management advisory purposes.

Observations and estimations using the results obtained from this study must be tempered with an appreciation of the limitations of the results. This will be kept in mind in the following illustration.

Farm No. 16 extends to 296 tillable acres. The cropping in 1957 included 46 acres of wheat, 126 acres of white pea beans and 85 acres of sugar beets. These are all high value crops. Yields in 1957 were lower than normal, largely because of the wet weather conditions. However, only 170 acres had been effectively tile drained. The poor drainage existing on the remainder had certainly contributed to the reduction in yields in 1957 and the yield potential in more normal years. The gross income achieved was $26,019 or $88.00 per acre, whereas the average gross income achieved in the sample was $110.00 per acre.

The quantities of inputs used on this farm in 1957 with their estimated marginal value products were:

Input	Quantity	Estimated MVP (dollars)	Estimated Geometric Mean MVP for the Sample (dollars)
Land	296 TA	25.00	24.06
Labor	51 months	177.63	306.87
Machinery investment	$17,795	.37916	.2968
Drainage investment	$21,551	.42721	.3020
Fertilizers and crop expense	$ 7,425	.75724	.5484

It will be assumed that farm size cannot be increased and will remain limited to the 296 acres.

Examination of the estimated MVP's shows that the marginal return to labor was lower than average with a higher than average return to machinery investment. This was not surprising in view of the high labor requirement on this farm for hand lifting of the sugar beets. Sixty-five acres were lifted by Mexican hand labor; the remaining 20 acres by custom machine harvesting at $20 per acre. With such a large acreage of sugar beets an investigation into the reduction in labor requirements and other costs by the purchase of a sugar beet harvester seemed in order. It is estimated that a reduction of 16 months of Mexican labor could be achieved by the purchase of a mechanical sugar beet harvester costing $3,500.

A partial budget would show:

<u>Increased costs:</u>		
Gas, oil, repairs, etc.	$400.	
Interest on investment @ 6%	210.	
Depreciation @ 20%	700.	
	$1,310.	
<u>Reduced costs</u>:		
16 months Mexican labor @ $170/month	$2,720.	
20 acres custom harvesting @ $20/acre	$ 400.	
	$3,120.	
Net reduction in annual costs		$1,810.

This would reduce costs sufficiently to enable the cost of the harvester to be met out of increased profits in two years.

If the other inputs remained fixed the effect on the estimated MVP's would be:

Land	$ 23.30	per tillable acre
Labor	$242.117	per month
Machinery investment	.2964	dollar per dollar
Drainage investment	.3982	" " "
Fertilizer and crop expenses	.7083	" " "

The MVP for labor has been increased considerably with a corresponding reduction in the MVP for machinery investment. Already an improvement in the adjustment has been achieved. A slight reduction in all the MVP's is noticed, this is due to a slightly lower estimated gross income.

The estimated MVP for drainage appeared to be very high, which is not surprising considering the large acreage still requiring tile drainage. Adequate drainage of the remainder would cost about $140 per acre requiring an increased investment of $17,640. A charge of 8 percent to cover interest on investment, depreciation and maintenance would result in increased annual costs of $1,411. It might be expected that under similar conditions existing in 1957, an income of $110 per acre should be achieved as fertilizer usage was not greatly different from the average. Increased returns would be $6,541, leaving a net increase of $5,130. This should enable repayment of the loan necessary to finance this increased investment within four years.

If these two major changes could be financed it would have the following effect on the estimated MVP's of the inputs:

Land	\$ 27.53	per tillable acre
Labor	\$276.99	per month
Machinery investment	.3391	dollar per dollar
Drainage investment	.2587	" " "
Fertilizer and crop expense	.8104	" " "

Estimated gross income had increased to \$35,248.00.

The farm now appears to be in much better adjustment with marginal returns more in line with minimum expected returns. (See page 41.) The estimated MVP of drainage had been reduced with substantial increases to the MVP's of the other input categories. This illustrates the reverse effect of the law of diminishing returns on the inputs held constant.

Mention has been made of the possibility of increasing returns by increasing the quantity of fertilizer applied to these crops on the now drained land. The estimated MVP for fertilizer and crop expense is less than \$1.06 (the suggested minimum return) which implies the higher input of fertilizer would be unprofitable. However, the reliability of this estimated MVP is questionable and outside evidence would support a decision to apply increased quantities of fertilizer.

Drained land is usually easier to manage and cultivate with fewer hold ups in work than undrained land. Hence, it is quite possible that other current crop expenses, such as gas and machinery repairs, would be reduced, thus tending to offset the suggested increase in fertilizer expense.

This example illustrates the use of the Cobb-Douglas type of analysis as a guide to advice on the individual farm. It thus complements usual farm management methods in helping to delimit general weaknesses in the farm business. The details required for making the ultimate decision being achieved by such practices as partial budgeting. This particular example also illustrates, in a simple way, the real advantage of being able to allocate a definite return to each of the machinery investment and labor input categories, thus giving a more objective basis for advice than labor efficiency measured in terms of productive work units per man.

The high profit point was then calculated for this farm with acreage assumed fixed at 296 acres. Unless one or more of the input categories are held constant a high profit point cannot be calculated as the sum of the b_i's is greater than one, i.e., increasing returns to scale.

At the high profit point (using the final Cobb-Douglas function) estimated gross income is $45,511. The land is now assumed to be fully drained, the increased investment necessary has already been computed. It was then computed that the optimum organization would mean altering the quantities of the other inputs to:

Labor	52 months
Machinery investment	$31,076.
Fertilizer and other expenses	$ 7,329.

After draining the remaining acreage the only input that appears to need radical change from the quantities used in 1957 is that of machinery investment. The need for a sugar beet harvester has already been examined. The other item of equipment lacking on this farm is a combine. A bean harvester is already owned but a spike-tooth combine capable of threshing beans would be an asset in view of the large acreage of beans which must be harvested quickly at a critical period. A new twelve foot self-propelled combine, of the type suggested, would cost about $7,500, which with the addition of the sugar beet harvester would bring the investment in machinery up to $28,795. This is nearer the suggested optimum investment.

The increase in the labor input could hardly be justified in practice, neither could the reduction in fertilizer and crop expense. At least another $700 could be spent on fertilizer to bring applications more in line with suggested optimum rates. It is also likely that the other crop expenses of gas, oil and machinery repairs would be increased due to the additional machinery.

Although caution must be taken in interpreting the results after calculating the high profit point, it is useful in that it gives the farm operator something to shoot for. It is also a guide as to the inputs which could be profitably increased or which need further examination.

CHAPTER VI

CONCLUSIONS AND APPLICATIONS IN THE UNITED KINGDOM

Conclusions

The cash crop farms of the Saginaw Valley and Thumb area of Michigan, represented by the sample in this study, appeared to be fairly well adjusted to the conditions existing in 1957. Improvements are likely to be obtained by new technology, such as improved varieties of crops, particularly wheat; better techniques of weed control, particularly in relation to sugar beets and beans; and improved methods of planting and/or thinning sugar beets. Labor efficiency will probably be largely improved by attention to the returns to other inputs as the ideal of equation (2), Chapter II, is approached. Some possibilities of reducing labor requirements have been noted but much improvement in this direction, except during the spring peaks, cannot be assumed.

A linear programming study in this area may show that a recombination of crops, either before or after these technical advances are made, could increase the returns to inputs. However, any improvement in this direction would be influenced by the strict allotments at present enforced for wheat and the acreage quota system for sugar beet growing. The build up of diseases in this area due to overcropping, particularly in relation to sugar beets and beans, will also dictate the pattern of crop combination in the not so distant future.

Higher yields might not automatically cause increases in the marginal productivities of the inputs. The demand for the main crops in this area is relatively inelastic so that price declines might result from increased production. Present conditions, therefore, would suggest attempting to improve the productivities of inputs within existing yields. Reduction in labor requirements per acre by increasing farm size and technological advances would appear to be another approach. This, of course, is in line with present economic thought and the trend to a larger business unit; but if this actually increases overall production, as the evidence of increasing returns to scale suggests, the farmer may be no better off. This observation is made with reservations because of the danger of extrapolating beyond the range of the data in this study. The lower return to machinery investment on the smaller farms, because of the relatively inflexible and expensive units of input required, also lends support to the trend to spreading this high investment over a larger acreage.

Adequate drainage is essential in this area. The study shows high returns were obtained to this investment in 1957 and other evidence[1] suggests that high returns are normally expected in average years. Further detailed investigation of returns to drainage investment over a longer period of time, may be worthwhile.

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[1]C. R. Hoglund, _op_. _cit_.

Applications in the United Kingdom

One of the original intentions in this research project was to study the substitution of machinery for labor in this area. Unfortunately, because the farms in the sample were generally well adjusted, and this appears typical of the area, insufficient differences occurred to pursue a detailed investigation of this nature. This was a disappointment because of the usefulness of such information in the U. K. However, one of the few maladjusted farms was selected to illustrate the applications of functional analysis at the micro level, and at the same time this illustrated a rather obvious case of the substitution of machinery for labor. This, in turn, illustrated the potentiality of the functional type of analysis to assist in the examination of the substitution of machinery for labor on less well adjusted farms. These are probably the case in the U. K., particularly in relation to labor and machinery.

The danger of high intercorrelations of the input categories reducing the reliability of the estimates of the regression coefficients is demonstrated by this study. Dr. Glenn L. Johnson, who supervised this study and has had considerable experience with this type of study, had not previously met with such high intercorrelations. Thus it is hoped that such an extreme example rarely occurs. Purposive sampling is a method of attempting to reduce the intercorrelations of the input categories, if this cannot be undertaken, the sample size must be increased to compensate.

The University agricultural economists, in the U.,K., have the time and facilities to do this. In the field, where the local farm management advisers and District Officers of the National Agricultural Advisory Service[2] are left to collect data from which farm business reports are compiled, time is an important factor. They are not usually in the position to undertake purposive sampling. However, the records are, or could be, made available to the Universities. This would enable larger samples covering similar types of farms over a wide area to be compiled; the danger of introducing more variables would have to be watched. Grouping of the farms is done strictly on an enterprise and farm size basis, as opposed to the Area Reports of the Michigan Co-operative Extension Service.[3] Hence more reliable estimates of regression coefficients may be obtained than has previously been achieved by using these records.[4] The recent institution of the "mail-in" system for collecting farm records by the Michigan Co-operative Extension Service could result in worthwhile estimates of marginal productivities to be made. The farm records collected in the U. K. would have to be improved somewhat to ensure more precise measurement of

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[2]The district Officer is almost the equivalent of the County Agent in the Co-operative Extension Service.

[3]Farm business reports issued by the Michigan Co-operative Extension Service are to be made available on a stricter farming type basis for 1957 onwards.

[4]Louis S. Drake, "Problems and Results in the Use of Farm Account Records to Derive Cobb-Douglas Value Productivity Functions" (unpublished Ph. D. dissertation, Department of Agricultural Economics, Michigan State College, 1952).

the input categories. The major difficulty would be streamlining the accounting procedure to make the newer measures of efficiency worthwhile, the objective use of which has been demonstrated in this study. It would also entail an extensive education program for the officers concerned regarding the theory behind, and the need for, such improvements to measures of farm business efficiency. Many found difficulty in grasping the principles of farm management analysis; currently employed and older members of the profession even ridiculed that approach as being unnecessary; hence, any further advances may have a difficult passage. A bias may result from the use of these farm records in that they are frequently assumed to be obtained from the better managed farms. Strictly speaking this would mean that any conclusions can only be applied to this group of farms. The same would therefore apply to conclusions reached by traditional methods from these farms. However conclusions would probably also apply to the so-called not-so-well managed farms, as the tendency is for them to be more poorly adjusted. It is the author's opinion that in the U. K. this difficulty would not tend to apply as the records obtained were fairly representative of managerial ability.

The problem of studying multiple enterprise farms has not yet been fully resolved;[5] as mixed farming is more general in the U. K. than the U. S. this problem is emphasized.

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[5] Christoph Beringer, *op. cit.*

This method of analysis should complement other methods of farm management work. They are not substitutes. A new slant on the farm business is obtained which gives a better basis for estimating efficiency. This is particularly helpful in relation to labor utilization and machinery investment. When making up standards of efficiency of farming assuming fixed acreage, most of the other inputs such as feed, fertilizer or livestock have measures of efficiency derived from independent input-output studies and more confidence can be placed in them. This is not so with the inputs of labor and machinery investment; these have little or no independent evidence from which measures of efficiency can be made. Supplementary studies to determine the marginal value productivity of labor for different crops and livestock would be useful in planning the best combination of enterprises where labor is the limiting factor. This is particularly so in the U. S., and the same position is rapidly approaching in the U. K.

Interpretation of the results for individual farms depends on how good a job is made of selecting homogeneous farms for the sample and the efficiency of measuring the input categories. Perhaps more important is the assumption inherent in the Cobb-Douglas production function of constant elasticity, although modifications can be introduced into the function to overcome this difficulty.[6]

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[6]A. N. Halter, H. O. Carter and J. G. Hocking, "A Note on the Transcendental Production Function," Journal of Farm Economics, Vol. XXXIV, Nov. 1957, pp. 966-974.

The method can also be applied to the study of resources at a macro level, to aid in the better all around allocation of these resources. For instance, the immigration of labor off the farms in the U. K. is continuing; increasing machinery investment and farm size may be part of the answer. Also pertinent is the recent Farm Improvements Bill which provides assistance in the modernization of buildings and other fixed investments to land. Many farmers, while welcoming the assistance, question whether this may be the best allocation of capital on their farms. Knowledge of the marginal value productivities of inputs would help give a more objective basis for consideration of these problems.

APPENDIX A

Estimated Marginal Value Productivities for Some of the Farms in the Sample

TABLE X

ESTIMATED MARGINAL VALUE PRODUCTIVITIES (DOLLARS) FOR SOME OF THE FARMS IN THE SAMPLE

	Farm 6		Farm 7		Farm 15		Farm 17		Farm 9		Farm 5	
	Quant.	Est.MVP	Quant.	Est.MVP	Quant.	Est.MVP	Quant.	Est.MVP	Quant.	Est.MVP	Quant.	Est.MVP
Land: undrained	93	28.22	76	29.14	79	29.19	93	34.30	106	25.41	138	28.19
drained		56.66		95.13		53.68		70.10		49.56		49.75
(tillable acres)												
Labor (months)	11	274.39	11.75	236.33	10.75	250.17	16.25	253.26	12	276.37	14	309.56
Machinery Invest. (dollars)	9299	.2418	6381	.3241	7277	.2740	13045	.2350	630	.29622	10315	.3129
Drainage Invest. (dollars)	12761	.2559	9578	.2878	11661	.2461	10122	.3921	12510	.2679	23951	.20521
Fertilizer & Crop Expense (dollars)	2673	.7010	3880	.4443	2795	.5945	5844	.4372	3161	.65117	4867	.55266
Actual Gross Income	12093		16594		9054		12799		14047		16510	

	Farm 11		Farm 20		Farm 30		Farm 2		Farm 4		Farm 14	
Land: undrained	131	25.80	146	22.64	146	33.93	212	18.25	214	19.12	209	19.17
drained		55.09		44.97		69.76		34.11		35.56		36.82
(tillable acres)												
Labor (months)	15	303.72	12.75	325.03	22	292.26	15.00	304.272	19.500	243.378	16.00	303.597
Machinery Invest. (dollars)	13845	.24501	17500	.20839	17015	.28144	11750	.2893	10147	.34835	11545	.31337
Drainage Invest. (dollars)	13800	.3055	15730	.2615	17620	.3498	12391	.38854	12700	.40078	13366	.37879
Fertilizer & Crop Expense (dollars)	4867	.55266	3308	.77751	12798	.31181	6499	.43586	5993	.49149	7143	.42206
Actual Gross Income	13731		14798		20919		19589		15210		17030	

TABLE X -- Continued

	Farm 16		Farm 3		Farm 19		Farm 24		Farm 31	
	Quant.	Est. MVP	Quant.	Est. MVP	Quant.	Est. MVP	Quant.	Est. MVP	Quant.	Est. MVP
Land: undrained	296	25.00	522	21.00	475	23.92	617	28.46	609	23.82
drained	51.00	48.48		39.62		45.31		51.42		48.23
(tillable acres)										
Labor (months)	51.00	177.630	45.00	290.098	58.00	234.238	64.00	312.927	32.5	570.501
Machinery Invest. (dollars)	17795	.37916	30410	.31972	3930	.25747	30015	.49696	49090	.28131
Drainage Invest. (dollars)	21551	.42721	35473	.38457	30488	.46380	76702	.28484	66334	.272129
Fertilizer & Crop Expense (dollars)	7425	.75724	11381	.71190	10334	.81594	19997	.62158	21736	.52943
Actual Gross Income	26019		53145		52922		75878		62846	

APPENDIX B

Questionnaire Used in Personal Interviews

CONFIDENTIAL

Farm No:

Tel. No:

Name:

Address:

Farm Size:

	Owned	Rented	Total
Tillable			
Non Tillable			
Woodland and other			
Total			

Tillable acreage leased out: Net tillable acres

Labor:

	Nos.	Months	Nos.	Days	Average man -month equivalents
Operator					
Family					
Hired: a. Full time					
b. Seasonal					
c. Mexican					

Total

Subtract labor for livestock

Net total labor for crop enterprises

Seasonal labor details (when and where used)

Wage details (flat rate, piece rate, bonus, etc.)

Housing facilities

Cropping	Acreage	Yield 1957	Yield Average
Wheat:			
Cash crop			
Certified seed			
Oats:			
Cash crop			
Certified seed			
Barley:			
Corn:			
Cash crop			
Certified seed			
Silage			
Beans:			
Cash crop			
Certified seed			
Sugar Beet:			
Other:			
Alfalfa & clover:			
Hay, silage and pasture			
Full season, unharvested green crop			
Green manure crop	( )		
Permanent pasture:			
Other			
Soil bank	( )		
Total			
Subtract acreage unconnected with cash crop production:			
Total Tillable crop acreage:			

Livestock numbers

Gross Income

Crop Income	Physical Production	1 Sales	2 Ending Valuation	3 Total 1+2	4 Beginning Valuation	5 Annual Production 3-4
Wheat: Cash crop	bu.					
Seed	bu.					
Oats: Cash crop	bu.					
Seed	bu.					
Barley:	bu.					
Corn: Cash crop	bu.					
Seed	bu.					
Beans: Cash crop	bu.					
Seed	bu.					
Sugar Beet	Tons					
Other						
Custom work & machine rented						
Produce consumed in house (not livestock)						
Other income from crop sources						
	Gross income, excluding livestock					$

Livestock income	1 Sales	2 Ending Valuation	3 Total 1+2	4 Beginning Valuation	5 Purchases	6 Total 4+5	7 Annual Prod. 3-6
Milk & other dairy produce							
Cattle							
Poultry & eggs							
Sheep & wool							
Other livestock income							

Gross livestock income $

Grand total $

Fertilizer & Lime

Analysis	Use	Quantity	Price	Cost
Lime				

Total $

Less that used for livestock crops $

Net cost to cash crop production $ ________

Residual Fertilizers & Lime: (cropland only)
Only if very different in beginning and ending inventory.
Difference in fertilizer and lime usage between 1957 & 1956 or the normal.

P_2O_5 lbs. difference x % = x ¢ = $

K_2O lbs. difference x % = x ¢ = $

N_2 lbs. difference x % = x ¢ = $

Difference in Residual Value $

Substract if difference balance is carried forward to 1958, or add if brought forward from 1956 and before.

Total Fertilizer & lime investment $ ________

Alterations in cropping during last 4 years:

Other expenses

	1 Beginning Valuation	2 Expenditure	3 Total	4 Ending Valuation	5 Annual Cost 3-4
A. Power & machinery:					
Custom work & machinery hire					
Fuel & oil for farm use (less refund)					
Implement & machinery repairs (not of an investment nature)					
Haulage					
Electricity (farm share)					
Auto operation (farm share)					
Other					
Total power & machinery costs					
B. Fertilizer & lime investment (p. 4)					
C. Seed					
D. Other:					
Baleing wire & sacks					
Crop sprays & pest control					
Postage, telephone, etc.					
Miscellaneous					
Total other costs					
Subtract or add value of difference in winter wheat, clover & alfalfa stands. (p. 6)					

Total crop expense $______

E. Livestock:					
Feed purchases:					
concentrates					
others					
Veterinary & medicine					
Breeding fees					
Other, dairy sundries etc.					

Total livestock expenses $______

Total of other expenses (crop & livestock) $______

Expenses not to include maintenance & repair work of an investment nature to buildings, machinery and land, or depreciation, interest & insurance charges.

Establishment and Valuation Winter Wheat, Clover & Alfalfa Stands

Only if there is a difference between beginning & ending inventory acreages (1957). Costs & values at 1957 prices.

Winter Wheat	1956 for 1957 crop	1957 for 1958 crop
Fertilizer costs per acre (excluding N_2 top dressing)		
Seed cost per acre		
Other costs		
Total per acre costs		
Multiplied by acreage		
Total cost of establishment of winter wheat		

Difference in cost or valuation $______

Clover & alfalfa seedings

Brought forward from 1956

Seeding	Acreage	Age	Condition	Value per acre	Value

Total value $______

Carried forward to 1958

Total value $______

Difference in valuation $______

NB Add valuations to crop expenses (p.5) if difference balance is brought forward from 1956, or subtract if carried forward to 1958.

Machinery & Equipment Investment

Item	No.	Age	Condition	Value
Tractors:				
Trucks:				
Combine				
Bean harvester				
Corn picker				
Sugar beet harvester				
Beet loader				
Bean windrower or rake				
Baler				
Bean, Beet or corn planter				
Grain drill				
Corn & grain handling: Elevator, Blower or Auger				
Drier				
Cleaning equipment				
Fertilizer distributor or lime spreader				
Seeder				
Spraying equipment				
Wagons & trailers				
Mower				
Cultivation equipment: __ bottom plow				
__ bottom plow				
Disc harrows				
Spring tooth harrows				
Drag or spike harrows				
Clod buster				
Cultipacker				
Field cultivator				
Roller				
Cultivator: row				
Rotary hoe				
Down the row thinner				
Leveller				
Grader or scraper				
Bulldozer				

Item	No.	Age	Condition	Value
Other crop machinery				
Workshop equipment:				
Welder				
Engines, motors				
Water pump				
General farm tools (forks, shovels etc.)				

Total crop machinery investment $________

Add proportion of investment for farm automobile $________

Livestock equipment

Mower				
Rake				
Forage harvester				
Blower				
Feed grinder				
Manure spreader				
Manure loader				
Dairy equipment				
Other livestock equipment				

Total livestock machinery investment $________

Beginning inventory, total machinery investment $________

Book value of machinery investment $________

*Note: Use beginning inventory & valuation at 1-1-57 values.

Purchases				Sales			
Date	Item	Total Cost	Prop. add.	Date	Item	Total Value	Prop. ded.

Beginning inventory:
Prop. added
Prop. subtracted ____________

Total machinery investment $________

Notes on machinery (ownership shareing?)

Buildings
Not to include that used for livestock & fodder or not used.

	Size	Farmers estimate of investment value
Machinery storage & workshop	Sq. ft.	
Crop storage:		
a. Small grains or beans	bu.	
b. Corn crib	bu.	
	Total	

Livestock buildings & fodder, forage etc.:

Farmers estimate of total building investment: $ ______________

Drainage (cropland only)

Undrained
- not requiring drainage ________ acres
- requiring drainage ________ acres

Drained
- good ________ acres
- fair, imperfect but cropable ________ acres
- very poor ________ acres

TOTAL crop acreage ________ acres

Tiles (discount old 2" tile systems)

Size	Type	Depth	Length of run in rods	Replacement cost per rod	Investment
4"					
5"					
6"					
8"					
10"					
12"					
over 12" (specity)					

Total tile investment $__________

Ditching (farm investment only)

Depth	Length of run in rods	Unit cost	Investment

Total ditch investment $________

Other drainage investment

Items		Investment
Land leveling		
Culverts		
Settling tanks		
Pumps		
Other		

Total $________

Investment charge for farm use of county ditches $________

Total drainage investment $________

Notes on drainage:

Assessment of farm practices used and labor & machinery organization

1. Cropping: (e.g. green manuring)

2. Cultivations: (e.g. minimal tillage)

3. Sowing

4. Preharvesting (e.g. pest & weed control)

5. Harvesting

6. Other crop handling procedures

If the operator could start afresh, what machinery & equipment would he have and how would this be combined?

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