A PARTIAL EVALUATION OF THE MICHIGAN TOWNSHIP EXTENSION PROGRAM IN DENMARK TOWNSHIP OVER THE PERIOD 1953 TO 1958, USING COBB-DOUGLAS ANALYSIS

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William Ross Bolger

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By

William Ross Bolger

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

Department of Agricultural Economics

1959

Approved by ________________

William Ross Bolger

ABSTRACT

The ultimate objective of this study was to ascertain whether the Michigan township extension program was more effective in increasing the efficiency with which resources were used on cash crop farms in Denmark township than was the traditional county extension program, over the period 1953 to 1958.

To achieve this objective, experimental farms (those serviced by the intensive township extension program) were matched with control farms (those serviced by the traditional county extension program) on the basis of certain criteria, calculated to insure that the only difference between the experimental and control farms was the greater amount of "on the farm" assistance which the township agent provided in the case of the experimental farms.

Cobb-Douglas analysis and certain traditional farm management efficiency indicators were used to indicate changes in the efficiency in the use of resources.

Cobb-Douglas analysis indicated that the following efficiency conditions, with respect to resource use, existed:

Input Category	1953	1958
	- Experimental Farms -	
land	maladjustment	in adjustment
labor	maladjustment	in adjustment
productive expenses	maladjustment	maladjustment
machinery investment	in adjustment	in adjustment
	- Control Farms -	
land	maladjustment	in adjustment
labor	in adjustment	maladjustment
productive expenses	in adjustment	in adjustment
machinery investment	in adjustment	maladjustment

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In the case of the 1953 experimental farms, there was maladjustment with respect to the use of land, labor and productive expenses; whereas, in the case of the 1953 control farms, there was maladjustment only in the use of land, relative to the other inputs. So, it appears that the 1953 control farms were using resources more efficiently, in the aggregate, than were the 1953 experimental farms. However, such was not the case at the termination of the study. Notice that, in the case of the 1958 experimental farms, there was maladjustment only with respect to productive expenses; whereas, in the case of the 1958 control farms, there was maladjustment in the use of labor and machinery. Thus, it appears that the 1958 experimental farms were using resources more efficiently, in the aggregate, than were the 1958 control farms. It should be evident, from the foregoing statements, that there was, in the case of the experimental farms, a significantly greater increase in the efficiency in the use of resources than there was in the case of the control farms.

The analysis bears out that, although both the experimental and control farms, at the outset, were operating under conditions of increasing returns to scale and, thus, could have increased the over-all efficiency with which resources were used by increasing the scale of operations,

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there were no appreciable changes in the scale of operations. Thus, it becomes apparent that the significant increase in the efficiency in the use of resources, in the case of the experimental farms over that of the control farms was due not to changes in the scale of operations but was due, instead, to the fact that resources came to be used more nearly in the proper proportions relative to each other. Hence, the Michigan township extension program was instrumental in increasing the efficiency with which resources were used on the experimental farms over that of the control farms, by virtue of the fact that the township agent was effective in advising farmers as to what changes in farm organization could be implemented which would result in resources being used more nearly in the proper proportions, relative to each other.

Insights gained by studying certain traditional farm management efficiency indicators suggested that there was a greater increase in the efficiency in the use of resources in the case of the experimental farms than there was in the case of the control farms, which is clearly consistent with the conclusion based upon Cobb-Douglas analysis.

It was ultimately concluded that the Michigan township extension program was effectual in increasing the efficiency with which resources were used on cash crop farms in Denmark Township over that of the traditional county extension program.

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TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The use of Cobb-Douglas analysis in extension research evaluation is of rather recent vintage.[1] Cobb-Douglas analysis will be used herein, in order to determine the levels of efficiency in the use of resources at two different periods in time, from which changes in the efficiency in the use of resources can be ascertained. Knowledge of such changes in the efficiency in the use of resources will then be used in evaluating, at least in a partial manner, the Michigan township extension program. The author recognizes that a complete evaluation of the Michigan township extension program should be presented in terms of a more ultimate

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[1]The author knows of no study which has used Cobb-Douglas analysis in actual extension evaluation research. However, he would hasten to indicate that Carl Eicher, a former graduate student, working with Dr. J. Nielson, in the Department of Agricultural Economics at Michigan State University, has made an important contribution in this respect. In his M.S. thesis entitled, The Use of Cobb-Douglas Analysis in Evaluating the Michigan Township Extension Program, Eicher discussed procedures to be followed by extension evaluators, when using Cobb-Douglas analysis in measuring changes in economic efficiency, resulting from some phase of extension education. In addition, Eicher developed statistical tests to compare the levels of efficiency in the use of resources between areas as well as over time. Generally, it can be said that Eicher's contribution was conceptual. While this thesis can also be said to deal with procedural problems, it is primarily concerned with the application of Cobb-Douglas analysis for the purpose of evaluating an extension program.

goal, namely, that of maximizing satisfaction. However, in view of the difficulties involved in measuring satisfaction,[2] the author is left with the more workable goal of optimum efficiency in the use of resources. Although there can well be a conflict between the goals of maximizing profit and maximizing satisfaction, the author believes that increased profits resulting from increased efficiency in the use of resources, over the range of incomes involved, will be reflected in increased satisfaction for the farmers, generally. The author also is convinced that any increase in the efficiency in the use of resources in agriculture can be regarded as a net gain to society as a whole. Since farmers and society as a whole are affected directly by changes in the efficiency in the use of resources, it seems that the author would be justified in basing his evaluation of the Michigan township extension program primarily on whether or not it was instrumental in increasing the efficiency with which resources were used in the farming area participating in the experiment.

The Michigan Township Extension Program

The Michigan township extension program, an experimental intensive program, was inaugurated in 1953, at which time the

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[2] Although it is possible to obtain an ordinal measure of satisfaction, it is impossible to obtain a cardinal measure of such.

W. K. Kellogg Foundation provided the Cooperative Extension Service of Michigan State University with funds necessary to organize, operate, and evaluate a more intensive extension program in five townships throughout the state for the five-year period, 1954-1958. The experiment was a cooperative project sponsored jointly by the W.K. Kellogg Foundation, the Cooperative Extension Service and the farmers who participated in the program. The contributions of the three cooperators in the project were as follows:

(1) The W.K. Kellogg Foundation made available a grant[3] which was intended to cover about one-half of the total cost of the program.

(2) Michigan State University made available specialists in agriculture and the social sciences, whose task it was to focus attention on problems peculiar to the areas studied.

(3) The participating townships made dollar contributions, in keeping with their financial resources.

To cite a mean figure, the townships' contributions

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[3]The Kellogg grant was intended to cover the costs involved in the coordination and evaluation of the experiment and to make up any discrepancy between the total cost of the program for each township and the amount which each township was able to contribute on a voluntary basis; other costs involved were met out of regular extension funds.

were in the neighborhood of $2500 per township, per annum. Local funds[4] were generally procured by members of the local board of directors[5] whose task it was to solicit voluntary contributions from participating farmers and local businessmen.

The major distinguishing feature of the township extension program was the greater amount of <u>on the farm</u> assistance which the township agents provided. Each of the five township agents concentrated his efforts on an average of 150 farms which represented a 16 fold reduction in the area and number of farmers normally assigned to a county extension agent in Michigan. On the average, the township extension agents spent more time <u>on the farm</u> assisting the farmers in the planning and management of their farm businesses than did the county agents. On the other hand, however, the township agents spent less time on such work as:

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[4] In general, farmers were not pleased with the manner in which local funds for the support of the program were raised. Many farmers, when asked if there was anything about the Michigan township extension program which should be changed, replied that the manner in which local funds were raised was unsatisfactory. As an alternative to raising funds by voluntary donations, they suggested that the funds be raised by including a charge for the services of the township agent on every participating farmer's tax bill.

[5] Each of the five townships elected a board of directors comprised of six or seven members all of whom were farmers. In addition to the board's aforementioned task, it was responsible for guiding the township agent in program development and execution.

extension organization, program planning and community development than did the county agents.

Objectives of the Township Extension Program

The all-embracing objective of the township extension program was to determine whether or not the more intensive township extension program was sufficiently effective to justify the additional costs involved as compared with the regular county extension program. More specifically, the objectives of the program as stated in the proposal[6] to the W.K. Kellogg Foundation were to:

1. Increase farm earnings.
2. Speed up the rate of adoption of improved farm practices.
3. Raise standards of living for farm families.
4. Improve rural communities.
5. Increase agricultural output.
6. Gain information on:
   a. effective extension methods
   b. organizational patterns and techniques
   c. communication skills
   d. community recreation

One glance at these objectives should serve to indicate

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[6] Proposal to the Kellogg Foundation for an Experimental Intensive Extension Program in Five Townships in Michigan, (prepared by the Cooperative Extension Service, Michigan State College, 1953), p. 2.

that an evaluation of any program which has such an all-inclusive list of objectives as were involved in this program, would, out of necessity, involve the analysis of numerous variables, in order to cast light on the nature of change -- knowledge of which is the prime requisite in the evaluation process.

Research Design of the Township Extension Program[7]

In order to ascertain the amount of change, if any, which might be attributed to the more intensive township extension program, samples of farmers were interviewed in each of the experimental townships.[8] Matched control areas were selected on the basis of:[9]

1. Markets
2. Soil associations
3. Types of farming

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[7] See Nielson, J. "Notes on the Research Design and Procedures for Evaluating the Township Extension Program", (unpublished document, Department of Agricultural Economics, Michigan State University, January, 1956).

[8] The townships and dominant farm types selected were:
Newton - heterogeneous as to farm type
Tri-Township - Northern Michigan dairy and potato
Denmark - Saginaw Valley cash crop
Almont - Southern Michigan dairy
Odessa - Southern Michigan dairy and general

[9] Nielson, J., "Farm Planning-Township Style", (a paper presented at the annual meeting of the New England Research Council, University of Vermont, June 24, 1954), p. 5.

4. Ethnic background of the farm people

5. County extension programs

   a. History of cooperation with extension in the area.

   b. Current extension programs

   c. Distance from the county extension office

   d. Availability of meeting places

6. Proximity to large cities

From each experimental township, farms, characterized by a wide range in size, were selected if they were found to be representative of the dominant farm type, provided that certain other criteria[10] were also met. From each control township, farms were chosen to match farms in the experimental township on the basis of:[11] age of operator, labor force, total acres, tillable acres, number of cows, and machinery investment. Following this procedure, the experimental townships were subjected to the more intensive township extension program, whereas the control areas were serviced by the traditional but less intensive county extension program. Other things being equal between each of the experimental and

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[10] These "other criteria" apply to conditions which farms had to meet in order to be included in a Cobb-Douglas analysis; these "other criteria" will be discussed later when dealing specifically with the Denmark samples.

[11] Nielson, "Farm Planning-Township Style", op. cit., p.6.

control areas, via the research design outlined above, the excess of change (if there were any) in the experimental over that of the control areas can be attributed to the more intensive extension program. However, if these "other things" are not equal,[12] then changes could not, with any degree of exactness, be attributed to the Michigan township extension program. To indicate the adequate nature of the research design involved, the author appeals to the authority vested in the following quotation from a publication by Nielson and Crosswhite,[13] "While no claim of perfect matching is made, the authors believe that the control samples match the experimental samples well enough to serve as highly useful check groups."

Information to be used in evaluating the township extension program was obtained in several ways. Foremost among these ways of obtaining information relevant to the study was the farm survey method. The benchmark survey provided information (1953 data) to be used in establishing beginning levels of efficiency. The terminal survey provided information (1958 data) to be used in establishing

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[12]Or randomly and normally distributed around a mean of zero so as to cancel each other out.

[13]Nielson, J. and Crosswhite, W., "The Michigan Township Extension Experiment - What Happened During the First Two Years," (Technical Bulletin 266, Michigan State University, Agricultural Experiment Station, February, 1958), p. 9.

ending levels of efficiency. By comparing the 1958 data with the 1953 data, changes which occurred can be determined. The intermediate survey provided information (1955 data) to be used in determining the sequence of change or, more generally, the manner of change, (i.e., how farmers got from where they were in 1953 to where they were in 1958). The farm survey schedules[14] included all the information needed to run a Cobb-Douglas analysis, all the information usually collected in a farm account project plus a net worth statement.[15]

To insure reliable and unbiased enumerating and thus uniformity in the data collected, the necessity (on the part of the enumerator) of being "an impartial observer and recorder of what people say and do" was stressed. Interviewers were instructed:[16] 1) to be sure to ask questions precisely as they appeared on the survey schedule, 2) to ask secondary questions only if necessary and to record the secondary question

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[14] About 40 farm survey schedules were taken for each of the experimental and control areas in 1954; the number of farm survey schedules taken in 1959 was somewhat smaller than in 1954 because of attrition.

[15] Nielson, J. "Farm Planning - Township Style", op. cit., p. 5.

[16] See "Instructions for Interviewers - Michigan Township Evaluation Research", available without charge from the Department of Agricultural Economics, Michigan State University.

if one were used, and 3) to record all answers "ad verbatum", in the first person.

In addition to the information obtained in the manner outlined above, interpretive information was acquired from case studies involving a small number[17] of participating farmers. Other useful information was obtained from township boards of directors, township agents, county agents, specialists, and administrative personnel.

Delineation of this Study in Relation to the Michigan Township Extension Program

Whereas an overall evaluation of the Michigan township extension program would involve all five experimental and control areas, this study, being a partial evaluation, will involve only one of the five areas, namely Denmark Township located in Tuscola County, in the thumb region of Michigan, as shown in Figure 1. Cash cropping predominates in this area, the major crops being, corn, beans, wheat and sugar beets. So it is that this study will be restricted in the sense that only farms in Denmark Township which qualify as cash crop farms will be studied. This study, out of necessity, will be restricted in yet another sense. On page 5, there

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[17] To attempt to do so for a large number would not be feasible nor economical.

RAND McNALLY

LOOSE LEAF OUTLINE MAP

MICHIGAN

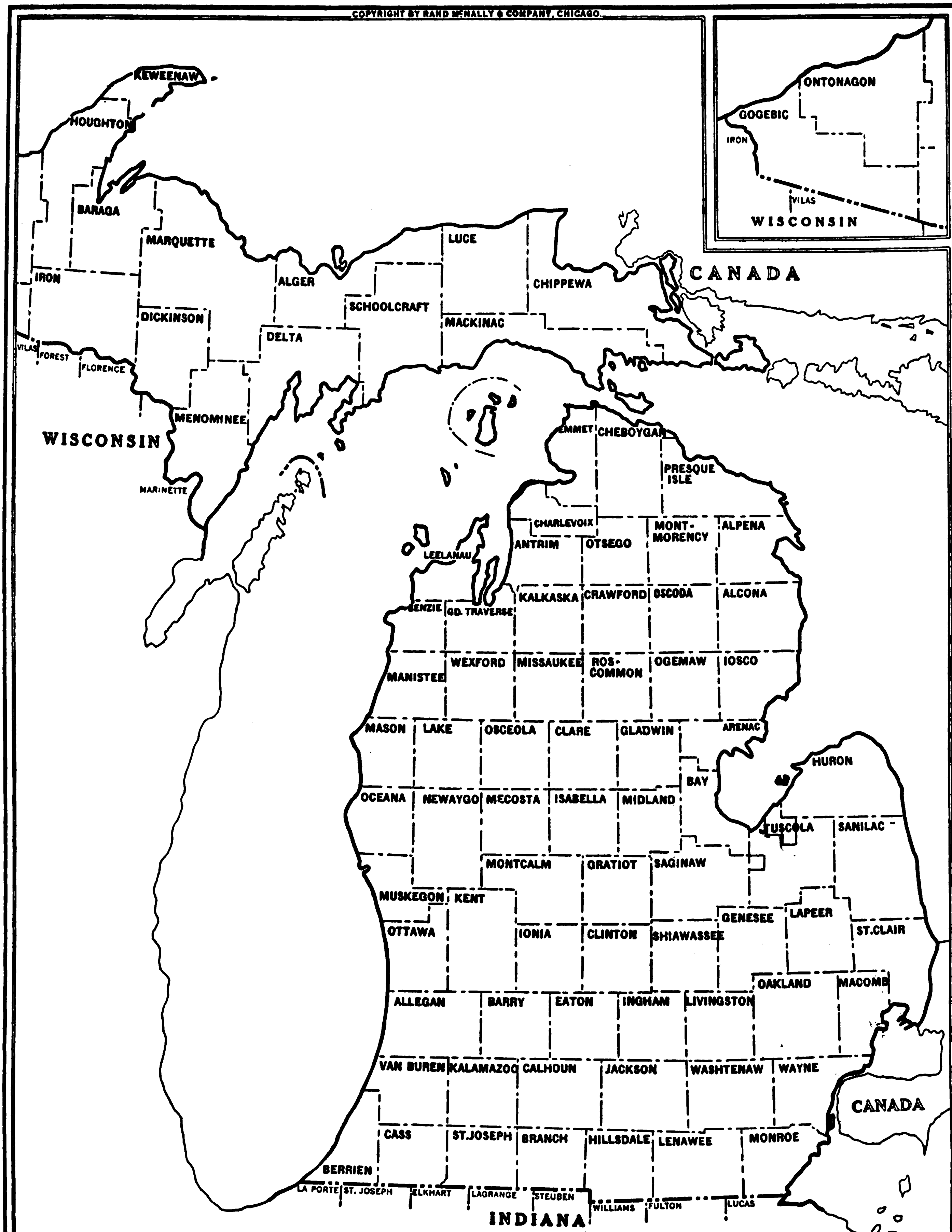

Figure 1 Outline Map of Michigan Showing the Area from which the Samples Were Drawn

0 5 10 20 30 40 50 60 MILES

MADE IN U.S.A. This Map is also available in size 17 x 22 159 OB 021 is a formal statement of the objectives of the Michigan township extension program. Of these six objectives, the author will be concerned directly with only three, namely, 1, 2, and 5. Hence, this study, as the title serves to indicate, is, in fact, a "partial" evaluation of the program.

Objectives of this Study

The ultimate objective of this study is to determine whether there has been a greater increase in the efficiency in the use of resources in the experimental area over that of the control area, which might be attributed to the Michigan township extension program.[18] The realization of this objective is dependent upon the realization of two intermediate objectives, namely: 1) to determine benchmark levels of efficiency for both the experimental and control areas and 2) to determine terminal levels of efficiency for both the experimental and control areas. Assuming that there have been changes in the efficiency in the use of resources, the author would pursue the study further in order to ascertain what changes have occurred which could be said to have 1) accompanied or 2) resulted in changes in efficiency. This involves an analysis of the nature and extent of changes

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[18] This statement presumes that the analysis will bear out that there has been an overall increase in the efficiency in the use of resources over the period studied.

in farm organization, in terms of changes in the input mix, for both the experimental and control areas.

The final objective of this study, in view of the importance of land and fertilizer as input factors in cash crop farming, is to determine the nature and extent of changes with respect to land use, fertilizer use, and crop yields.

Thesis Organization

Chapter II will deal with "the data", which discussion will involve the delineation of steps to be taken in order to insure that the data meet the necessary conditions for Cobb-Douglas analysis. Considerations bearing upon the validity of the results will be discussed therein. The second section of Chapter II will deal with processing the raw data from the initial procedures to the final categorization of such. The final section of Chapter II will deal with factor pricing by input categories.

Chapter III will deal with the methodology in two parts. The first section will deal with Cobb-Douglas methodology, unique to this study. The second section will deal with the methodology involved in determining changes in land use, fertilizer use and crop yields.

Chapter IV will deal with Cobb-Douglas Analysis, and the interpretation of such.

Chapter V will deal with efficiency changes as reflected by traditional farm management efficiency indicators.

Chapter VI will deal with changes in land use, fertilizer use, and crop yields.

Chapter VII will present summary statements and overall concluding remarks.

CHAPTER II

GATHERING AND CATEGORIZING THE DATA

Definite procedures were followed to insure that the data collected would meet the specifications of the study.

Procedures to be Followed to Insure that Conditions for the Application of Cobb-Douglas Be Met

An important prerequisite to the realization of accurate results, when applying Cobb-Douglas analysis to farm survey data, is the use of as wide a range of data as is possible with respect to the proportions and quantities of inputs used in production. For instance, it is important to select, on the one hand, farms, characterized by their use of much labor relative to other inputs, namely land, machinery, etc., and, on the other hand, farms characterized by their use of little labor relative to other inputs.
By following this procedure for all of the inputs, it is possible to obtain a sample of farms, characterized by:
1) a high degree of variance with respect to the inputs used in production and 2) a low degree of intercorrelation among input categories. Accuracy can be further enhanced by increasing sample size and/or by minimizing the sum of the squared residuals. By following any or all of these procedures, the standard errors of the regression coefficients,

σb_{x_1}'s, are reduced,[1] as can be seen from the following formula:[2]

$$\sigma b_{x_1} = \sqrt{\frac{\Sigma U^2}{N \sigma_{x_1}^2 (1 - R_{x_1}^2 (x, \ldots x_h, x_j \ldots x_n)}}$$

Where:

ΣU^2 is the sum of the squared residuals (to be minimized).

N is sample size[3]

σx_1^2 is the variance in the factor - factor dimension (to be maximized), and

$R_{x_1}^2(x, \ldots x_h, x_j \ldots x_n)$ is the inter-correlation among the independent variables (to be minimized).

The necessary requirement for the validity of least squares regression analysis is that the sum of the squared

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[1]Although it is impossible to place statistical limits on the accuracy of the marginal value productivity estimates, as is done in the case of regression coefficients, it would appear that the greater the degree of accuracy with which the regression coefficients are estimated the more precise would be the estimates of the marginal value productivities.

[2]Ezekiel, M., Methods of Correlation Analysis, (second edition, New York: John Wiley and Sons, Inc., 1949), p. 502.

[3]Sample size should be increased to the limit at which the marginal cost of the last survey schedule is just equal to the marginal value of the information gained by taking the last survey schedule.

residuals be minimized. The sum of the squared residuals will, in all likelihood, be minimized if: 1) there is homogeneity in both the studied (e.g. land) and the unstudied (e.g. weather conditions) variables, 2) the correct form of the equation is used, 3) an adequate number of variables is used, and 4) an adequate number of observations is used. Minimizing the sum of the unexplained residuals was accomplished in Denmark Township by choosing a group of experimental farms which were homogeneous with respect to soil type, climatic conditions, etc., by virtue of limiting the study to a limited geographic area. Control farms, which were homogeneous with respect to the aforementioned factors, were selected to match the experimental farms. This procedure was followed to insure that all farms selected had about the same inherent productivity.

N can be varied in accordance with the degree of accuracy desired and the cost which the researcher is willing to incur. Since survey samples are costly, strict economy as to sample size becomes very important, which precludes the possibility of reducing the $\sigma_{b_{xi}}$'s significantly by increasing sample size.[4]

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[4]The marginal utility of increased information, as a result of increasing N, might well be less than the marginal cost of acquiring more information (in the case of random sampling).

But what can be said regarding the two remaining means of reducing the $\hat{\sigma}_{b_{x_i}}$'s? What technique can be employed which will minimize the inter-correlations among input categories, while at the same time maximize the variances of the independent variables? It should be apparent that random sampling will not achieve this desired end, because, as a general rule, farms selected in such a manner tend to be clustered around the high profit point, which tendency results in a high degree of inter-correlation among the input categories. Due to this lack of range in the data, the estimates of the regression coefficients and, hence, the estimates of the marginal value productivities are likely to be significantly in error unless sample size is very large.[5] Thus, it becomes evident that the sampling device employed must allow one to observe the farms in advance to insure that, in aggregate, the sample of farms chosen is characterized by a wide range[6] of observations with respect to the independent variables. The

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[5]The cost involved in getting a very large random sample is usually prohibitive.

[6]A check on the range obtained in the sample can be acquired by plotting pairs of input categories between which a high degree of inter-correlation is thought to exist. If a relatively high correlation were found to exist between land and labor, farms could be sought which were using both greater and lesser amounts of land relative to labor.

sampling technique designed to permit the achievement of this end is called purposive sampling.[7] At the outset, it was intended that purposive sampling be used in acquiring sample farms in Denmark Township. However, the sampling technique used was not "purposive" in the stricter sense of the word in that there simply were not enough potential cooperators available from which to choose a truly purposive sample. Be that as it may, the sample farms obtained in Denmark Township were characterized by a wide range with respect to the proportions and quantities of inputs used in production -- a prerequisite to the realization of small standard errors (of the regression coefficients) and accurate results in general.

Another condition which must be met to insure the validity of Cobb-Douglas analysis, is that all farms must be operating on the same production function.[8] Implicit in this statement are the necessary requirements that all farms:

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[7] Purposive sampling is more efficient than random sampling in that it allows one, with a sample comprised of fewer farms, to get just as good or better results as one could get using random sampling techniques involving invariably a larger sample size. This is so, because, by using purposive sampling techniques, one is able to choose a wide range of farms which are not in competitive adjustment, which allows a smaller sample size than the random sampling technique would permit.

[8] All farms must be on the same production function, because the production function, estimated using the Cobb-Douglas technique, while it is derived from data secured from a group of farms, is regarded as the production function for each individual farm.

1) have about the same inherent productive capacity,
2) be using the same range of technology from the given bundle of technology which is available,
3) be using inputs within each input or investment category in least cost combination,
4) be of the same type,
5) be using the same categories of inputs, and
6) be operated by managers possessing a similar degree of managerial ability.

Although one would not expect to find these six conditions fulfilled in any group of farms selected, these are the conditions which should be approached to insure the realization of valid results.

It is not known definitely how well the farms comprising the Denmark Township experimental and control samples met these conditions. However, it is known that much effort was expended in attempting to insure that such conditions would be met. There were two instances in which it is definitely known that the Denmark Township samples fell somewhat short of fulfilling these conditions. The first of these was that, while the vast majority of the farms included in the sample had no livestock or very little, not all of the farms, in the stricter sense of the word, could be said to be single enterprise cash crop farms. Hence, in fitting the functions, only those farms which realized the majority of their incomes from cash cropping could be used. To have included all farms in fitting the functions would have resulted in problems similar to those dealt with by Beringer,[9] namely, the difficulties involved in estimating marginal value productivities for multiple enterprise farms. The second instance involved the requirement that all farms must be using the same input categories. While many of the farms did not have any livestock, some did. Hence, it was decided that, for the purpose of explaining as much of the variation in the dependent variable (gross income), as was possible, in terms of variation in the independent variables (input categories), the livestock-forage investment category would be included in fitting the functions. Thus, in those cases in which farms did not have any livestock-forage investment, it was necessary to use a "dummy" variable.[10] So it is evident that, inasmuch as this study fell somewhat short of fulfilling the aforementioned conditions, it was primarily due to the fact that some farms, which realized part of their incomes

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[9] Beringer, C., "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, (edited by Heady, Johnson and Hardin, Ames, Iowa: Iowa State College Press, 1956).

[10] One dollar was used as the "dummy" variable in cases in which the livestock-forage investment was zero, since the log of zero is undefined.

from livestock, were included in fitting the functions. However, the author would assure the reader that, in fitting the functions, there were good reasons for including some farms which had some livestock, the income from which in no case exceeded 40 percent of gross income. Initially, in the Denmark experimental and control samples, there were 39 farms each. Sample size was reduced somewhat by attrition, which in the case of Denmark, was not very significant.[11]

The potential number of farms to be used in fitting the functions was further reduced by the necessity of meeting the condition (for the first fit) that no farm could be included in fitting the functions if it had 40 percent or more of its income accruing from livestock. In addition, the number of farms to be used in fitting the functions was further reduced in view of the necessity of meeting the condition (for the second fit) that a farm could not be used in fitting the 1953 functions, unless it was also used in fitting the 1958 functions and vice versa.[12] This matter was intensified

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[11] "Drop-outs" numbered three in the experimental area and two in the control area over the period 1953 to 1958.

[12] It was decided that farms which met the criteria for use in fitting the functions in 1953, but did not in 1958, and vice versa, would not be used at all (for the second fit). If this condition were not adhered to, one would not get a true measure of change on particular farms, but instead would get a compound measure of change composed of: 1) changes which occurred on the same farms over the period 1953 to 1958 plus 2) changes which resulted from the fact that certain farms used in fitting the 1958 functions very well might not have been used in fitting the 1953 functions and vice versa. It is the latter type of change, i.e., change due to changes in sample composition, which must be eliminated, if one is to be rigorous.

by the fact that shifts in farm organization occurred to the extent that some farmers, who in 1953, had less than 40 percent of their incomes accruing from livestock, had more than 40 percent of their incomes accruing from livestock in 1958. There were also shifts in the other direction, in that farmers, who in 1953, had more than 40 percent of their incomes accruing from livestock, had less than 40 percent, or in some cases none of their incomes accruing from livestock in 1958.

To meet the condition of using only those farms in fitting the functions which could be used in fitting both the 1953 and 1958 functions, sample size, N, was reduced to 27 in the case of the control sample and 24 in the case of the experimental sample. To have reduced N further to eliminate all those farms with some income from livestock, would have resulted in increasing the standard errors of the regression coefficients to the point where one would place little confidence, if any, on the reliability of the marginal value productivity estimates. Having made these abating statements, the author would hasten to suggest that all the farms used in this study do quite satisfactorily meet the necessary conditions for using every one of them in fitting the functions, since, in all cases, the major portion of their gross incomes was derived from cash cropping.

Procedures Followed in Categorizing the Data

In that much has already been written regarding the categorization of inputs,[13] it will be discussed only briefly herein. Inputs are aggregated into input or investment categories in order: 1) to reduce the number of variables to manageable proportions and 2) to focus more clearly on the complex economic problem of imperfect complementarity and imperfect substitutability. The reasons for categorizing inputs infer, implicitly, the procedures which should be followed. One rule, which follows logically, is to group good complements together and good substitutes together, measuring the complements in terms of sets (e.g., one tractor--one plough) and the substitutes in terms of the least common denominator (e.g., 2-12-10 fertilizer substitutes for 4-24-20 in the ratio of 2: 1). These sets of complements and sets of substitutes should be grouped into input categories, putting those which are good complements to, or good substitutes for, each other in the same input category. By so doing, the complex economic problem, involving imperfect complementarity and imperfect substitutability, is

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[13]See for example, Bradford, L. and Johnson G., Farm Management Analysis, (New York: John Wiley and Sons, Inc., 1953), p. 144.
Johnson, G., "Classification and Accounting Problems in Fitting Production Functions to Farm Record and Survey Data", Resource Productivity, Returns to Scale and Farm Size, op. cit., pp. 90-91.

brought to the fore, where it can be studied more readily. This, then, is the theory upon which the categorization of inputs is based.

In fitting the functions, the following variables were involved:[14]

a) the dependent variable:

X_1 gross income, in dollars

b) the independent variables:

X_2 land, in tillable acres

X_3 labor, in months

X_4 productive expenses, in dollars

X_5 livestock-forage investment, in dollars

X_6 machinery investment, in dollars

X_7 fertilizer expense, in dollars

Gross Income (X_1) includes total cash receipts from the sale of all produce, plus or minus inventory changes with respect to livestock, feed, seed, etc., and the value of family living furnished by the farm. Items not included in gross income were: 1) government payments, since they were not regarded as income from farm-produced products and 2) changes in the inventory values of buildings and machinery due to depreciation;[15] hence gross income should be large

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[14] See "Summary Sheet for Cobb-Douglas Analysis", Appendix A, p. 82.

[15] Since depreciation charges were not included in productive expenditures, expected to yield a dollar return plus interest on a dollar spent, changes in the inventory values of buildings and machinery were excluded from gross income.

enough to cover depreciation and upkeep on buildings and machinery.

Land (X_2) includes the total number of tillable acres owned, rented, and/or leased by the farm operator. So as to obtain an accurate estimate of the productivity of land, woodlots and other waste land were excluded from this category.

Labor (X_3) includes the total number of months of labor used on the farm during the year, which includes the operator's labor, family labor and hired labor.[16] Several farm operators worked off the farm part-time, which was taken into account in determining the number of months of operator's labor used.

Productive expenses (X_4) includes all expenses expected to yield a dollar plus interest return per dollar spent in

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[16]This figure had to be adjusted upwards in many cases to include Mexican labor employed to block and thin sugar beets, but not recorded as part of the hired labor figure. In a few cases, in which physical quantities of Mexican labor were recorded, the adjustments were made by merely adding the reported figure to the hired labor figure. More typically than not, however, the amount of Mexican labor employed was recorded in dollar terms, in which case the following steps were taken. The dollar figure was converted to hours by multiplying by four-thirds (Mexicans received 75¢ per hour). The hourly figure was then reduced to a monthly figure by dividing by 250 (Mexicans worked a 10 hour day and a 25 day month). The final adjustment was made by adding the number of months of Mexican labor to the number of months of hired labor. Thus, the total labor input figure in months was a summation of the operator's labor, family labor, hired labor and Mexican labor employed on the farm.

any given year. This category thus includes the following items: feed purchased, annual seeds and plants purchased, custom work or machinery hired, supplies purchased, gas and oil for farm use (less tax refund, of course), livestock expense, farm share of electricity and telephone expenses, farm share of auto and truck expenses and upkeep, beginning inventory of feeders and/or broilers, feeders purchased, beginning value of clover stands, and beginning value of perennials destroyed prior to June 1. Certain nonproductive expenses such as depreciation charges, insurance charges, taxes, repairs, maintenance on investments, etc., were excluded from this input category. As a result of excluding these nonproductive expenses, reservation prices,[17] to be used in determining the economic optimum, must be high enough to cover such nonproductive expenses.

Livestock-forage investment (X_5), a "hybrid" investment category,[18] so to speak, includes the total dollar investment in breeding livestock[19] and forage crops. The total

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[17] See p. 31, for reservation prices used in this study.

[18] Livestock and forage investments, although computed separately, are commonly combined to form a single input category because of the high degree of correlation and complementarity between livestock and forage investments.

[19] For the purpose of this study only dairy cattle, namely, dairy bulls, cows, heifers, and calves, were regarded as breeding stock. All other livestock was regarded as feeder stock and, thus, was included in the productive expenses input category.

livestock investment was computed by taking the beginning inventory value of all breeding stock, plus a proportional cost for breeding stock purchased during the year, minus a proportional credit for breeding stock sold during the year.[20]

The total forage investment was computed by taking the beginning inventory value[21] of all hay and pasture stands (i.e., all perennial and second year clover stands), minus a proportional credit[22] for perennials destroyed, plus the cost of machinery hired for land reclamation,[23] plus the value of perennial seeds purchased and used during the year.

<u>Machinery investment</u> (X_6) includes the beginning of the year auction value of all machinery and equipment, plus a proportional addition for machinery purchased during the year, minus a proportional deduction for machinery sold during the year.[24]

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[20]See Appendix A, p. 86, for the procedures followed in calculating proportional costs and credits for breeding stock.

[21]See Appendix A, pp. 84-85, for the values used in the hay and pasture evaluation.

[22]See Appendix A, p. 85, for the procedures followed in calculating proportional credits for perennials destroyed.

[23]The cost of machinery hired for land reclamation was not often incurred; however, when the cost of such, if not in excess of 100 dollars, was incurred, it was counted as part of the forage investment.

[24]See Appendix A, p. 87, for the method used in calculating proportional additions and proportional deductions for machinery.

<u>Fertilizer expense</u> (X_7), includes the total expenditure on fertilizer purchased and used during the year. In view of the importance of fertilizer as an input in cash crop farming, the author deemed it meritous of special consideration. Consequently, fertilizer expense was studied as a separate input category.[25]

[25] On the basis of information obtained from fitting the functions once the decision was made to combine fertilizer expenses and productive expenses, hence eliminating fertilizer expense as a separate input category.

CHAPTER III

METHODOLOGY FOR DETERMINING EFFICIENCY CHANGES

Determining Changes in Efficiency as Indicated by Cobb-Douglas Analysis

In view of the fact that the literature[1] abounds with discussions regarding the methodological procedures to be

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[1] See for example, Beringer, C., A Method of Estimating Marginal Value Productivities of Input and Investment Categories on Multiple Enterprise Farms, (unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, 1955).

Bradford, L.A., and Johnson, G.L., op.cit.

Brooke, D.M., Marginal Value Productivities of Inputs on Cash Crop Farms in the Thumb and Saginaw Valley Area of Michigan, 1957, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State University, 1958).

Drake, L.S., 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).

Eicher, C., The Use of Cobb-Douglas Analysis in Evaluating the Michigan Township Extension Program, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State University, 1956).

Resource Productivity, Returns to Scale and Farm Size, op.cit., see especially Chapters I, XI, and XVI.

Tintner, G., "A Note on the Derivation of Production Functions from Farm Account Records", Econometrica, Vol. 12, No. 1, (January, 1944), pp. 26-34.

Tintner, G. and Brownlee, O., "Production Functions Derived from Farm Records," Journal of Farm Economics, Vol. 26, (August, 1944), pp. 566-571.

Toon, T., Marginal Value Productivities of Inputs, Investments and Expenditures on Upland Grayson County Farms During 1951, (unpublished M.S. Thesis, University of Kentucky, 1952).

Wagley, R., The Marginal Productivities of Investment and Expenditures, Selected Ingham County Farms, 1952, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State College, 1953).

adhered to when the Cobb-Douglas function is used for the purpose of estimating marginal value productivities of various input and investment categories on farms, the author shall take the liberty of limiting this section to the task of outlining the methodological procedures which were unique to this study.

The initial procedure was to fit the functions in order to determine the b_i's (the regression coefficients) from which the estimates of the marginal value productivities of the various input and investment categories were derived.

The next step was to compare the estimated b_i's with the b_i's necessary to hield, at the margin, returns equal to a set of minimum expected returns, for the various input categories. Minimum expected returns at the margin or alternatively reservation prices, in this case, were taken to be the expected returns to the various input categories just sufficient to invoke the use of the inputs in production. But what is this return, which at the margin is just sufficient to invoke the use of the input (or in this case the input category)? It is none other than the MFC (marginal factor cost) of the input (or input category). Hence, it becomes apparent that by comparing the estimated b_i's with the b_i's to yield minimum returns at the margin, one actually obtains a measure of the divergence of the MVP's of the various input categories from their respective MFC's which in turn, gives one a satisfactory measure of the efficiency with which resources were being used. Reservation prices,[2] from which b_i's to yield minimum expected returns at the margin were derived, are presented in Table 1.

TABLE 1

Reservation Prices

Input Category	Units	1953	1958
Land	Dollars per tillable acre	18.00[1/]	30.00[2/]
Labor	Dollars per month	150.00[3/]	158.00[4/]
Productive expenses	Dollars per dollar expended	1.06[5/]	1.06[5/]
Livestock-forage investment	Percent on investment	40.00	40.00
Machinery investment	Percent on investment	21.00[6/]	24.00[7/]
Fertilizer expense	Dollars per dollar expended	1.06[8/]	1.06[8/]

[1]This was based on a 6 percent charge for interest (5 percent) and taxes (1 percent), with land valued at $300 per acre.

[2]This was based on a 6 percent charge with land valued at $500 per acre.

[3]This was based primarily on Eicher's figure (op.cit., p. 74); the author deems it suitable for use in this study in as much as Eicher's was a similar study involving 1953 data for an adjacent county, namely Lapeer, wherein approximately the same alternative opportunities for labor were prevalent.

[4]This was derived from the 1953 value by adjusting it upwards in accordance with the increase (5.5 percent over the period

[2]Reservation prices were established as a result of diligent study of original sources and discussion with Dr. J. Nielson, Department of Agricultural Economics, Michigan State University.

1953 to 1958) in the annual average farm wage rate index for Michigan, see Farm Labor, Agricultural Marketing Service, United States Department of Agriculture, (Washington, D.C.: Government Printing Office, January, 1959). Although the reservation price of $158 for the last month of labor for 1958 was derived by adjusting the 1953 reservation price for labor in accordance with the increase in the farm wage rate index for Michigan, the reader might question the validity of it, suggesting that a somewhat higher reservation price should have been used. Inasmuch as the author anticipated that such a question might arise, optimal b_i's for labor were derived for 1958 using reservation prices of: 1) $200 per month and 2) $250 per month. When reservation prices of $200 per month and $250 per month were used, the resulting efficiency conditions were not statistically different from the efficiency conditions when a reservation price $158 per month was used. Thus, the author decided to use a reservation price of $158 per month -- the price which is in accordance with the increase in the farm wage rate index for Michigan, over the period 1953 - 1958.

[5] This was based on the fact that productive expenses should return a dollar plus interest at 6 percent per dollar expended.

[6] This was based on the following charges: 9 percent for depreciation, 5.5 percent for maintenance and repairs, .5 percent for taxes, and 6 percent for interest.

[7] This was based on the same charges as were used in 1953 plus an additional charge of 3 percent to take account of increasing costs of repairs and maintenance over the period 1953 to 1958.

[8] This was based on the fact that fertilizer expense should return a dollar plus interest at 6 percent per dollar expended.

In establishing these reservation prices no allowance was made for risk. Since risk is a highly personal and subjective factor, which varies from farmer to farmer, to have allowed 2 percent, 5 percent, or 10 percent would have been unrealistic. Having said this, the author would hasten to say that risk is an important factor which farmers do take into account. Hence, anyone using these results for the purpose of assisting a farmer with problems involving changes in farm organization must take risk into account as it applies in the particular case at hand.

The optimal b_i's (b_i's to yield MVP's equal to minimum expected returns at the margin) were derived by substituting the respective reservation prices in the appropriate MVP equations, the general form of which is given by:

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

where Y is predicted gross income and X_i is the geometric mean amount of the particular input category under consideration. These equations were in turn solved for the optimal b_i's. The estimated b_i's were compared with the optimal b_i's to ascertain whether or not there was maladjustment with respect to the proportions in which resources, by input category, were being used. To determine whether or not there was a significant difference between the respective b_i's, the following statistic[3] which has a "t" distribution with N - 1 - p degrees of freedom, was used:

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[3]Dixon, W., and Massey, F., Introduction to Statistical Analysis, (second edition, New York: McGraw-Hill Book Co., Inc., 1957), p. 115.

$$t = \frac{b_i - b'_i}{\sigma b_i}$$

where: b_i is the estimated regression coefficient

b'_i is the optimal b_i

σb_i is the standard error of the b_i

N is the sample size

p is the number of independent variables.

If, for instance, the estimated b_{land} were significantly different from the optimal b_{land}, one would conclude that the MVP_{land} was significantly different from the MFC_{land}, i.e., that there was maladjustment with respect to land.[4] If, on the other hand, the estimated b_{land} were not significantly different from the optimal b_{land}, one would conclude that the MVP_{land} was not significantly different from the MFC_{land}, i.e., that there was no apparent maladjustment in the use of land. The same procedure was followed in studying the b_i's of the other input categories.

In order to determine whether or not there were a significant difference between the experimental and control functions for 1953 and 1958, respectively, a special "t" test[5]

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[4]If the estimated b_i were significantly different from the optimal b_i, and since the b_i value is reflected in MVP value, one could justifiably conclude that the estimated MVP was significantly different from its respective MFC (from which the optimal b_i was derived) which would indicate that there was maladjustment with respect to land.

[5]See Appendix B, pp. 88-90

was constructed by which the regression coefficients of the experimental function were to have been tested for significance against the respective coefficients of the control function. However, this test was not used, because large variance in the dependent variables precluded the possibility of obtaining significant "t" values, even though the test stands up under statistical scrutiny.

For the same reason as was cited above, it was impossible to obtain significant "t" values for differences between 1953 b_i's and their respective 1958 b_i's.

In order to determine whether or not the sum of the b_i's for each function were significantly different from 1, a statistic[6] which has an "F" distribution was derived. However, since the data[7] required for the test were not readily available, the test was not used. Thus, statistical evidence was not available to support or reject possible contentions regarding returns to scale. Yet, it becomes apparent that this was not a serious handicap from the standpoint of this study, when one realizes that it was more

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[6]See Appendix B, p. 90

[7]The augmented moment matrix was available but could not be used in this case. The inverse matrix, which was applicable in this case and, hence, could have been used, was not readily available.

meaningful to compare the differences between the sum of the b_i's for 1953 and 1958 for the experimental and control functions, respectively, which was in fact done. By so doing, changes in the nature of returns to scale were determined.

While it was generally decided that, if there turned out to be a significant increase in the efficiency in the use of resources in the experimental area over that of the control area, such would be attributed to the intensive township extension program, the author recognized the necessity of maintaining a watchful eye throughout the analysis, in order to ascertain whether the increase in efficiency should have been attributed, in part at least, to certain factors other than the intensive township extensive program.

An alternative to following the procedures outlined above would have been to have used Trant's[8] method of adjusting MVP estimates for changing prices. Following Trant's method, the 1953 MVP estimates would have been adjusted to the 1958 price level, thus eliminating the effects of inflation and deflation over the period studied. To have followed Trant's method would have allowed one to make

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[8]Trant, G.I., A Technique of Adjusting Marginal Value Productivity Estimates for Changing Prices, (unpublished M.S. Thesis, Michigan State College, 1954).

direct comparisons, by input categories between the 1953 MVP's, adjusted to 1958 price conditions, and the 1958 MVP's. However, this method was not followed because, in the author's opinion, while it no doubt is interesting to know that the MVP of machinery for 1953 was 20 percent on investment and that the MVP of machinery for 1958 was 25 percent on investment, it is more meaningful to compare MVP's with their respective MFC's, for both the base and terminal periods, to determine whether the MVP of machinery for 1958 came more nearly to equality with the MFC of machinery for 1958 than was the case in 1953. So, it becomes apparent that in attempting to ascertain the nature of efficiency changes, that the really relevant consideration is not by what percent did the MVP of machinery increase over the period studied, but rather, how did the MVP of machinery change relative to the MFC of machinery.

Determining Changes in Farm Resource Organization as Indicated by Changes in the Geometric Mean Amounts of Inputs Used

Changes in farm organization relate to shifts along the production function, i.e., changes in farm organization occur when input substitution causes a change in gross income. Farm organization changes were determined by ascertaining what changes occurred with respect to the geometric mean amounts of inputs which were used in the experimental area as opposed to the control area over the period studied.

Determining Changes in Efficiency as Indicated by Traditional Farm Management Efficiency Indicators

Changes in efficiency as indicated by certain traditional farm management indicators of efficiency were examined in order to determine whether or not they were consistent with changes in efficiency as indicated by Cobb-Douglas analysis. The analysis of such was carried out using a "t" test[9] which was employed to indicate whether or not there were significant changes with respect to certain traditional farm management efficiency indicators in the experimental and control areas, over the period studied.

While it would have been desirable to have used a "t" test to determine whether or not there were significantly greater changes with respect to traditional farm management efficiency indicators in the experimental area over that of the control area, or vice versa, such was not possible; due to correlation, the ordinary "t" test was invalidated in that

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[9]The hypothesis involved was that there was no significant difference between population means. The following statistic was used to test the hypothesis:

$$t = \frac{\Sigma D}{\sqrt{\dfrac{N\Sigma D^2 - (\Sigma D)^2}{N - 1}}}$$

where D is the difference between observations and N is the sample size.

the calculated "t" value was biased downward, in accordance with the degree of correlation, (i.e., the greater the degree of correlation, the greater the downward bias in the "t" value). Thus, it should be apparent that "t" values, calculated without taking the degree of correlation into account, would have been too conservative, i.e., the calculated "t" values would have been smaller than the actual (but unknown) "t" values. Since the degree of correlation between the experimental and control data was unknown, the degree of downward bias in the calculated "t" value, for any particular item, was also unknown. Thus, inasmuch as accurate "t" values were not obtainable, the author chose to make statements, based solely upon his judgment, as to whether or not there were significantly greater changes in the experimental area over that of the control area, or vice versa.

Determining Changes in Land Use, Fertilizer Use and Crop Yields

The methodology used in studying changes in land use, fertilizer use, and crop yields was practically the same as that used in studying changes in traditional farm management efficiency indicators. The only difference between the two was in the use of statistical evidence in support of statements regarding the significance of changes. That is, statements regarding the significance of changes with respect to traditional farm amnagement efficiency indicators were based partly upon statistical evidence and partly upon the author's judgment; whereas, statements regarding the significance of changes with respect to land use, fertilizer use, and crop yields were based solely upon the author's judgment.

CHAPTER IV

EFFICIENCY CHANGES AS INDICATED BY COBB-DOUGLAS ANALYSIS

As indicated in Chapter II, seven variables were initially used in fitting the functions. However, high simple correlations were found to exist between fertilizer and land, fertilizer and labor, and fertilizer and machinery. It is generally recognized that such high intercorrelation jeopardizes the accuracy of the estimated b_i's and hence the reliability of the MVP's. In an attempt to reduce the high intercorrelation present, fertilizer expense was combined with productive expenses, thus eliminating fertilizer expense as a separate input category. By so doing, the simple intercorrelations were reduced substantially, thus, improving considerably the reliability of the b_i's. Therefore, the results obtained using seven variables in fitting the functions were not used in the evaluation process.

Acting in the light of the information presented above, two sets of functions were fit, using six variables. For the first fit, involving six variables, unmatched farms were used; whereas for the second fit, involving six variables, matched farms were used.[1] The reasons for fitting the

[1] In the case of the first fit, farms were unmatched in the sense that farms were used in fitting the 1953 functions whether or not they were used in fitting the 1958 functions. In the case of the second fit, farms were matched in the sense that only those farms, which met the criteria for use in both 1953 and 1958, were used in fitting the functions.

functions, first, for unmatched farms and secondly, for matched farms were: 1) to ascertain whether or not the differences between the estimates obtained were sizeable, and 2) to determine the effects of reducing sample size to eliminate unmatched farms. The differences in the estimates obtained by using matched farms rather than unmatched farms were generally not important; yet, it was deemed discreet, for the purpose of this study, to use only matched farms in the evaluation process. By so doing, it was possible to ascertain actual changes in efficiency on the same farms over the period 1953-1958. Had unmatched farms been used in the evaluation process, the estimates of change obtained would have been compound[2] in the sense that the estimates of change would have included actual changes on matched farms plus changes due to differences in sample composition. Thus, only the functions involving six variables and including only matched farms are reported herein.

Analysis of the Experimental Function, 1953

The 24 farms[3] which were used in fitting the function yielded b_i's and $\hat{\sigma}_{b_i}$'s as shown in Table 2. Notice that the

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[2] See p. 21, footnote 12

[3] See Appendix C, p. 92, where the observations, summarized by input categories, are presented.

b_i's for land and productive expenses, when tested against the null hypothesis,[4] were found to be significant at the

TABLE 2

Regression Coefficients (b_i's), Their Standard Errors (σb_i's), "t" Values, and Level of Significance, Experimental Function, 1953.

Input Category	b_i	σb_i	t	Significant[1] at Level Indicated(%)
X_2, land	.548881	.141894	3.86	5
X_3, labor	-.153513	.151263	1.01	40
X_4, expenses	.521516	.120951	4.31	5
X_5, livestock-forage	.021142	.019587	1.07	30
X_6, machinery	.047448	.105597	.44	70
X_1, gross income				
Σb_i	.984			

[1]For N-1-p = 18 degrees of freedom, where p = number of independent variables.

five percent level of significance. Notice also that the b_i for labor was negative; however, it was not significantly different from zero at the five percent level of significance. Thus, the b_i for labor was assumed to be zero and the Σb_i value was adjusted upwards by .153, which gave an adjusted $\Sigma b_i = 1.137$.

The multiple correlation coefficient (R) was found to be .94, indicating a high degree of association between

[4]The hypothesis was that the regression coefficients, taken individually, were not significantly different from zero.

the dependent and independent variables.

The coefficient of determination (R^2) of .88 indicates that 88 percent of the variance in gross income was associated with the independent variables. R^2 was found to be significantly[5] different from zero at the one percent level of significance.

The standard error of estimate ($\bar{S}$) was computed to be .086695 in logarithms, while the logarithm of gross income at the geometric mean was 4.123510. Thus, in 67 percent of the cases, under 1953 conditions, the logarithms of gross income would be expected to fall within the range defined by 4.123510 $\pm$ .086695 or, in natural numbers, between \$10870. and \$16230.

The geometric mean amounts of inputs used and the MVP's which relate to these are presented in Table 3. These MVP figures represent the gross return to the marginal unit of each input or investment category. Hence, the last tillable acre of land was returning \$53.25, the last month of labor was returning a negative \$141.48, the last dollar of productive expenses was returning \$1.57, the last dollar invested

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[5] The hypothesis was that the true $R^2 = 0$. The statistic used was $\frac{R^2}{1-R^2} \cdot \frac{N-p-1}{p} = F$ for p and N-p-1 degrees of freedom, where p = number of independent variables.

in forage-livestock was returning 28 percent or $.28 and

TABLE 3

Usual Organization, Marginal and Gross Value Products, Experimental Function, 1953

Input Category	Geometric Mean Amounts of Inputs	MVP (in dollars)
X_2, land	136.8 tillable acres	53.25
X_3, labor	14.4 months	-141.48
X_4, productive expenses	$4388.	1.57
X_5, livestock-forage	$9.5	.28
X_6, machinery	$7369.	.085
X_1, gross income	$13272.	1.024891
log a		1.024891

the last dollar invested in machinery was returning 8.5% or $.085.

When interpreting MVP's it is important to consider carefully the degree of intercorrelation between the various input categories, because it is well recognized that high intercorrelation between any two input categories can introduce bias in the estimation of the b_i's, which, in turn, is reflected in unreliable MVP's estimates. The simple intercorrelations, in this case, were as follows:

r_2r_3	.62	r_2r_4	.65	r_2r_5	.53	r_2r_6	.65
r_3r_4	.62	r_3r_5	.75	r_3r_6	.48		
r_4r_5	.47	r_4r_6	.63				
r_5r_6	.30						

It can be seen, by examining the intercorrelations, that only in the case of r_3r_5, labor and livestock-forage, was there a high degree of intercorrelation. In all other cases the degree of intercorrelation was relatively low.

Analysis of the Control Function, 1953

The 27 farms[6] which were used in fitting the function yielded b_i's and σb_i's as shown in Table 4. Notice that the b_i's for land, productive expenses and machinery, when tested against the null hypothesis, were significant at the five percent level of significance. Notice also that $\Sigma b_i = 1.28$, indicating increasing returns to scale.

TABLE 4

Regression Coefficients (b_i's), Their Standard Errors (σb_i's), "t" Values, and Level of Significance, Control Function, 1953.

Input Category	b_i	σb_i	t	Significant[1] at Level Indicated(%)
X_2, land	.574956	.198569	2.89	5
X_3, labor	.141152	.123829	1.13	30
X_4, productive expenses	.314875	.129919	2.42	5
X_5, livestock-forage	-.004804	.013573	.35	80
X_6, machinery	.255337	.121452	2.10	5
X_1, gross income				
Σb_i	1.28			

[1]For N-1-p = 21 degrees of freedom, where p = the number of independent variables.

The multiple correlation coefficient (R) was found to be .95, indicating a high degree of association between the

[6]See Appendix C, p. 93 where the observations, summarized by input categories, are presented.

dependent and independent variables.

The coefficient of determination (R^2) of .90 indicates that 90 percent of the variance in gross income was associated with the independent variables. R^2 was found to be significantly different from zero at the one percent level of significance, using a statistic which followed the "F" distribution for 5 and 21 degrees of freedom.

The standard error of estimate ($\bar{S}$) was found to be .089907 in logarithms, while the logarithm of gross income at the geometric mean was 4.079573. Thus, in 67 percent of the cases, under 1953 conditions, the logarithms of gross income would be expected to fall within the range defined by 4.079573 ± .089907 or, in natural numbers, between \$9764. and \$14780.

The geometric mean amounts of inputs used and the MVP's which relate to these are presented in Table 5. By examining the MVP values, it becomes evident that the last tillable acre of land was returning \$51.26, the last month of labor was returning \$106., the last dollar of productive expenses was returning \$1.06, the last dollar invested in livestock-forage was returning a negative 32 percent, and the last dollar invested in machinery was returning 42.5 percent.

The simple intercorrelations were as follows:

r_2r_3 .58 r_2r_4 .78 r_2r_5 −.09 r_2r_6 .71

r_3r_4 .52 r_3r_5 .02 r_3r_6 .64

r_4r_5 .25 r_4r_6 .53

r_5r_6 -.16

TABLE 5

Usual Organization, Marginal and Gross Value Products, Control Function, 1953

Input Category	Geometric Mean Amounts of Inputs		MVP (in dollars)
X_2, land	134.6	tillable acres	51.26
X_3, labor	16.	months	106.
X_4, productive expenses	\$3568.		1.06
X_5, livestock-forage	\$18.2		-.32
X_6, machinery	\$7206.		.425
X_1, gross income	\$12000.		
log a			.587980

It can be seen, by examining the intercorrelations, that the highest degree of intercorrelation existed between land and productive expenses, while the next highest degree of intercorrelation existed between land and machinery. Otherwise, the degree of intercorrelation was relatively low.

Analysis of the Experimental Function, 1958

The 24 farms[7] which were used in fitting the function yielded b_i's and σb_i's as shown in Table 6. Notice that the b_i for productive expenses, when tested against the null

[7]See Appendix C, p. 94 where the observations, summarized by input categories, are presented.

TABLE 6

Regression Coefficients(b_i's), Their Standard Errors($\hat{\sigma}b_i$'s), "t" Values, and Level of Significance, Experimental Function, 1958.

Input Category	b_i	$\hat{\sigma}b_i$	t	Significant[1] at Level Indicated(%)
X_2, land	.295832	.200760	1.47	20
X_3, labor	.313313	.228412	1.37	20
X_4, productive expenses	.534822	.126719	4.22	1
X_5, livestock-forage	.009900	.018698	.52	70
X_6, machinery	.047372	.118422	.40	70
X_1, gross income				
Σb_i	1.19			

[1]For N-1-p = 18 degrees of freedom, where p = number of independent variables.

hypothesis, was found to be significant at the one percent level of significance, while the b_i's for land and labor were found to be significant at the 20 percent level of significance. The Σb_i value in this case was 1.19.

The multiple correlation coefficient (R) was found to be .94, indicating a high degree of association between the dependent and independent variables.

The coefficient of determination (R^2) of .88 indicates that 88 percent of the variance in gross income was associated with the independent variables. R^2 was found to be significantly different from zero at the one percent level of significance, using a statistic which followed the "F" distribution with 5 and 18 degrees of freedom.

The standard error of estimate (S), was found to be .105425 in logarithms, while the logarithm of gross income at the geometric mean was 4.183615. Thus, in 67 percent of the cases, under 1958 conditions, the logarithms of gross income would be expected to fall within the range defined by 4.183615 ± .105425 or, in natural numbers, between \$11970. and \$19450.

The geometric mean amounts of inputs used and the MVP's which relate to these are presented in Table 7. By examining the MVP values, it becomes evident that the last tillable acre of land was returning \$30.44, the last month of labor was returning \$291.53, the last dollar of productive expenses was returning \$1.73, the last dollar invested in livestock-forage was returning 76 percent, and the last dollar invested in machinery was returning 9.7 percent.

TABLE 7

Usual Organization, Marginal and Gross Value Products, Experimental Function, 1958

Input Category	Geometric Mean Amounts of Inputs	MVP (in dollars)
X_2, land	148.3 tillable acres	30.44
X_3, labor	16.4 months	291.53
X_4, productive expenses	\$4718.	1.73
X_5, livestock-forage	\$19.71	.76
X_6, machinery	\$7439.	.097
X_1 gross income	\$15260.	
log a	.999756	

The simple intercorrelations were as follows:

r_2r_3	.81	r_2r_4	.67	r_2r_5	.19	r_2r_6	.59
r_3r_4	.73	r_3r_5	.04	r_3r_6	.56		
r_4r_5	.25	r_4r_6	.49				
r_5r_6	.30						

It can be seen, by examining the intercorrelations, that the highest degree of intercorrelation existed between land and labor and between labor and productive expenses. The degree of intercorrelation otherwise was relatively low.

Analysis of the Control Function, 1958

The 27 farms[8] which were used in fitting the function yielded b_i's and $\hat{\sigma}b_i$'s as shown in Table 8. Notice that the b_i's for land, labor and machinery, when tested against the null hypothesis, were found to be significant at the five percent level of significance. The $\leq b_i$ value, in this case, was 1.35, indicating increasing returns to scale.

The multiple correlation coefficient (R) was found to be .93, indicating a high degree of association between the dependent and independent variables.

The coefficient of determination (R^2) of .87 indicates that 87 percent of the variance in gross income was associated with the independent variables. R^2 was found to be

[8]See Appendix C, p. 95 where the observations, summarized by input categories, are presented.

TABLE 8

Regression Coefficients (b_i's), Their Standard Errors (σb_i's), "t" Values, and Level of Significance, Control Function, 1958

Input Category	b_i	σb_i	t	Significant[1] at Level Indicated(%)
X_2, land	.268980	.123255	2.18	5
X_3, labor	.566922	.129665	4.37	5
X_4, productive expenses	.254063	.125223	2.02	10
X_5, livestock-forage	-.010749	.012859	.83	50
X_6, machinery	.289199	.095935	3.01	5
X_1, gross income				
Σb_i,	1.35			

[1]For N-1-p = 21 degrees of freedom, where p = number of independent variables.

significantly different from zero at the one percent level of significance, using a statistic which followed the "F" distribution with 5 and 21 degrees of freedom.

The standard error of estimate (S) was found to be .081101 in logarithms, while the logarithm of gross income at the geometric mean was 4.121146 $\pm$ .081101 or, in natural numbers, between \$10961 and \$15931.

The geometric mean amounts of inputs used and the MVP's which relate to these are presented in Table 9. By examining the MVP values, it becomes evident that the last tillable acre of land was returning \$22.72, the last month of labor was returning \$435.44, the last dollar of productive expenses was returning \$.99, the last dollar invested in

TABLE 9

Usual Organization, Marginal and Gross Value Products, Control Function, 1958

Input Category	Geometric Mean Amounts of Inputs	MVP (in dollars)
X_2, land	156.4 tillable acres	22.72
X_3, labor	17.2 months	435.44
X_4, productive expenses	$3405.	.99
X_5, livestock-forage	$15.8	-8.9
X_6, machinery	$8309.	.46
X_1, gross income	$13211.	
log a	.812505	

livestock-forage was earning negative returns,[9] and the last dollar invested in machinery was returning 46 percent.

The simple intercorrelations were as follows:

r_2r_3	.56	r_2r_4	.68	r_2r_5	-.07	r_2r_6	.26
r_3r_4	.59	r_3r_5	.09	r_3r_6	.15		
r_4r_5	.06	r_4r_6	.41				
r_5r_6	-.29						

It can be seen, by examining the intercorrelations, that the highest degree of intercorrelation existed between land

[9]The author did not expect to obtain reasonable results for the livestock-forage input, because many farmers had no livestock-forage investment, in which case a "dummy" variable of $1. was used. The livestock-forage investment category was included for the purpose of explaining as much of the variation in the dependent variable, as was possible, in terms of variation in the independent variables--<u>not</u> to obtain reliable MVP estimates for it. Hence, no further analysis will be applied to the livestock-forage investment category.

and productive expenses. The degree of intercorrelation, in all cases, was relatively low.

Regarding the Efficiency with Which Resources Were Used by Input Categories

As indicated in Chapter III,[10] the efficiency with which resources were used, by input categories, was determined by testing the estimated regression coefficient (b_i) for each input category against its respective optimal regression coefficient (b_i'), to ascertain whether or not there was a significant difference between the two. The results of these tests are presented forthwith.

Experimental Farms, 1953

Comparisons between the estimated b_i's and the optimal b_i's are presented in Table 10. Notice that the estimated b_i of land was significantly different from its optimal b_i at the five percent level of significance. Thus, one would conclude that the MVP of land was significantly different from the MFC of land, i.e., that there was maladjustment in the use of land relative to other inputs.[11] The estimated

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[10]See pp. 31-34

[11]The purpose of this section is to indicate, by input category, whether or not there were maladjustment in the use of resources. The nature of the maladjustment can be determined by comparing MVP's with their respective MFC's. See Table 15, p. 61

b_i of labor was significantly different from its optimal b_i at the ten percent level of significance. Hence, it was

TABLE 10

Comparisons Between the Estimated Regression Coefficients (b_i's) and the Optimal Regression Coefficients (b_i''s), Experimental Farms, 1953

Input Category	b_i	b_i'	b_i-b_i'[1]	$\hat{\sigma}_{b_i}$	$t=\frac{b_i-b_i'}{\hat{\sigma}_{b_i}}$	Significant[2] at Level Indicated(%)
X_2, land	.548881	.185533	.363348	.141894	2.56	5
X_3, labor	.153513	.162748	.316261	.151263	2.09	10
X_4, prod. ex.	.521516	.340539	.180977	.120951	1.49	20
X_6, machinery	.047448	.117763	.070315	.105597	.66	60

[1]Absolute value.
[2]For N-1-p = 18 degrees of freedom, where p = number of independent variables.

concluded that there was maladjustment in the use of labor relative to other inputs. The estimated b_i of productive expenses was significantly different from its optimal b_i at the 20 percent level of significance.[12] The author thus concluded that there was maladjustment with respect to productive expenses, relative to other inputs. Since the b_i of machinery was not significantly different from its optimal b_i, at the 20 percent level of significance, or lower, it was concluded that there was not maladjustment in the use of machinery relative to other inputs.

Control Farms, 1953

Comparisons between the estimated b_i's and the optimal b_i's are presented in Table 11. The estimated b_i of land was

[12]It was decided that the 20 percent level of significance should be regarded as the critical level.

significantly different from its optimal b_i at the ten percent level of significance. Thus, it was concluded that there was maladjustment in the use of land relative to other inputs.

TABLE 11

Comparisons Between the Estimated Regression Coefficients (b_i's) and the Optimal Regression Coefficients (b_i''s), Control Farms, 1953

Input Category	b_i	b_i'	b_i-b_i'[1]	$\hat{\sigma}b_i$	$t=\frac{b_i-b_i'}{\hat{\sigma}b_i}$	Significant[2] at Level Indicated(%)
X_2,land	.574956	.201900	.373056	.198569	1.87	10
X_3,labor	.141152	.199375	.058223	.123829	.47	70
X_4,prod.ex.	.314875	.314875	--	--	--	--
X_6,machinery	.255337	.126105	.129232	.121452	1.06	50

[1]Absolute value.
[2]For N-1-p = 21 degrees of freedom, where p = number of independent variables.

Since none of the other estimated b_i's was found to be significantly different from their respective optimal b_i's, it was concluded that there was not maladjustment in the use of labor, productive expenses or machinery, relative to one another.

Experimental Farms, 1958

Comparisons between the estimated b_i's and the optimal b_i's are presented in Table 12. The estimated b_i of productive expenses was significantly different from its optimal b_i at the 20 percent level of significance. Hence, it was concluded that there was maladjustment with respect to productive expenses, relative to other inputs. Since none of the other estimated b_i's was found to be significantly different from

TABLE 12

Comparisons Between the Estimated Regression Coefficients (b_i's) and the Optimal Regression Coefficients (b_i''s), Experimental Farms, 1958

Input Category	b_i	b_i'	$b_i - b_i'$[1]	$\hat{\sigma}_{b_i}$	$t = \frac{b_i - b_i'}{\hat{\sigma}_{b_i}}$	Significant[2] at Level Indicated(%)
X_2, land	.295832	.291546	.004286	.200760	.02	--
X_3, labor	.313313	.169803	.143510	.228412	.62	60
X_4, prod.ex.	.534822	.327724	.207098	.126719	1.33	20
X_6, machinery	.047372	.116996	.069624	.118422	.58	60

[1]Absolute value.
[2]For N-1-p = 18 degrees of freedom, where p = the number of dependent variables.

the respective optimal b_i's, it was concluded that there was not maladjustment in the use of land, labor, or machinery, relative to one another.

Control Farms, 1958

Comparisons between the estimated b_i's and the optimal b_i's are presented in Table 13. The estimated b_i of labor was significantly different from its optimal b_i at the five percent level of significance. Thus, it was concluded that there was maladjustment in the use of labor relative to other inputs. Since the estimated b_i of machinery was significantly different from its optimal b_i at the 20 percent level of significance, it was concluded that there was maladjustment in the use of machinery relative to other inputs. Since neither the estimated b_i of land nor the estimated b_i of

TABLE 13

Comparisons Between the Estimated Regression Coefficients (b_i's) and the Optimal Regression Coefficients (b_i''s), Control Farms, 1958

Input Category	b_i	b_i'	$\lvert b_i - b_i' \rvert$[1]	$\hat{\sigma}_{b_i}$	$t = \frac{b_i - b_i'}{\hat{\sigma}_{b_i}}$	Significant[2] at Level Indicated(%)
X_2, land	.268950	.355158	.086178	.123255	.69	50
X_3, labor	.566922	.205707	.361211	.129665	2.78	5
X_4, prod.ex.	.254063	.273204	.019141	.125223	.15	90
X_6, machinery	.289199	.150946	.138252	.095935	1.44	20

[1]Absolute values.
[2]For N-1-p = 18 degrees of freedom, where p = number of independent variables.

productive expenses was significantly different from its respective optimal b_i', it was concluded that there was not maladjustment with respect to land and productive expenses, relative to each other.

Regarding the Efficiency With Which Resources Were Used in the Aggregate

Efficiency conditions with respect to resource use are summarized, by input categories in Tables 14 and 15. Considering Table 14, initially, notice that, in the case of the 1953 experimental farms, there was maladjustment in the use of land, labor, and productive expenses; whereas, in the case of the 1953 control farms, there was maladjustment only in the use of land relative to other inputs. Hence, it would seem logical to conclude that, in the aggregate, the 1953 control farms were in better adjustment than were the 1953 experimental farms. So it was that the 1953 control farms were at an advantage, relative to the 1953 experimental farms, at the outset, so far as efficiency in the use of resources was concerned. However, at the termination of the program, such was not the case. By referring to Table 14, it can readily be seen that, in the case of the 1958 experimental farms, there was maladjustment only with respect to productive expenses, whereas, in the case of the 1958 control farms, there was maladjustment in the use of labor and machinery. Thus, it would seem reasonable to conclude that, in the aggregate, the 1958 experimental farms were in better adjustment than were the 1958 control farms.

Further insights regarding efficiency conditions can be gained by studying Table 15, which presents comparisions between MVP's and their respective MFC's, by input categories, and, thus, serves to indicate: 1) the nature of efficiency conditions and 2) the adjustments which were necessary if optimum efficiency in the use of resources were to have been achieved.

In view of the evidence presented in Tables 14 and 15, it would seem logical to conclude that there was a significant increase in the efficiency in the use of resources, by input categories as well as in the aggregate, in the case of the

TABLE 14

Efficiency Conditions With Respect to Resource Use by Input Categories, Experimental and Control Farms, 1953 and 1958

Input Category	1953	1958
	Experiment Farms	
X_2, land	b_1 was significantly different from b_1' at the 5% level of significance, indicating maladjustment with respect to land use.	in adjustment
X_3, labor	b_1 was significantly different from b_1' at the 10% level of significance, indicating maladjustment in the use of labor.	in adjustment
X_4, productive expenses	b_1 was significantly different from b_1' at the 20% level of significance, indicating maladjustment with respect to productive expense.	b_1 was significantly different from b_1' at the 20% level of significance, indicating maladjustment with respect to productive expenses.
X_6, machinery investment	in adjustment	in adjustment
	Control Farms	
X_2, land	b_1 was significantly different from b_1' at the 10% level of significance, indicating maladjustment with respect to land use.	in adjustment
X_3, labor	in adjustment	b_1 was significantly different from b_1' at the 5% level of significance, indicating maladjustment in the use of labor.
X_4, productive expenses	in adjustment	in adjustment
X_6, machinery investment	in adjustment	b_1 was significantly different from b_1' at the 20% level of significance, indicating maladjustment in the use of machinery.

TABLE 15

Efficiency Conditions With Respect to Resource Use, by Input Categories, as Indicated by Comparing Marginal Value Products (MVP's) With Their Respective Marginal Factor Costs (MFC's), Experimental and Control Farms, 1953 - 1958

Input Categories	1953 MVP (in \$)	1953 MFC (in \$)	1953 Adjustments Needed to Achieve Optimum	1958 MVP (in \$)	1958 MFC (in \$)	1958 Changes in Efficiency Conditions	1958 Adjustments Needed to Achieve Optimum
			Experimental Farms				
X_2, land	53.25	18.00	Use more land relative to other inputs	30.44	30.00	Came into adjustment	No adjustment needed
X_3, labor	-141.48	150.00	Use less labor	291.53	158.00	came into adjustment	No adjustment needed
X_4, productive expenses	1.57	1.06	Incur more productive expenses	1.73	1.06	Approximately the same degree of maladjustment	Incur more productive expenses
X_6, machinery investment	.085	.21	No adjustment needed	.097	.24	No change	No adjustment needed
			Control Farms				
X_2, land	51.26	18.00	Use more land	22.72	30.00	Came into adjustment	No adjustment needed
X_3, labor	106.00	150.00	No adjustment needed	435.44	158.00	Went out of adjustment	Use more labor
X_4, productive expenses	1.06	1.06	No adjustment needed	.99	1.06	No change	No adjustment needed
X_6, machinery investment	.425	.21	No adjustment needed	.46	.24	Went out of adjustment	Use more machinery

experimental farms over that of the control farms.[13]

But what were the factors which can be said to have caused the efficiency conditions, which prevailed at the outset, to have changed? Such changes in efficiency conditions, over time can be said to be the result of: 1) changes in regression, i.e. changes in the input mix, and/or 2) changes in factor prices, which are reflected in changes in the optimal b_i's. It will be recalled (see Tables 14 and 15) that, in 1953, land was out of adjustment relative to other inputs, for both the experimental and control farms; however, in 1958, land was in adjustment. This adjustment in land use was the result of changes in the aforementioned factors, namely, lower estimated regression coefficients and a higher factor price for land, as shown in Table 16, in which changes in the socalled determinants of efficiency conditions are presented. Table 16 serves to indicate that changes in the efficiency conditions were primarily due to changes in regression. Of the two determinants of changes in efficiency conditions, it can be seen that, even in the case of land, changes in regression were more important than the change in the factor price of land.

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[13] The control farms were actually in worse adjustment in 1958 than they were in 1953.

Thus, in the light of the evidence presented so far, the author would conclude that the increase in the efficiency in resource use on the experimental farms over that of the control farms is attributable to the Michigan township extension program.

TABLE 16

Changes in the Determinants of Efficiency Conditions With Respect to Resource Use, by Input Categories, Experimental and Control Farms, 1953 - 1958

Input Category	Changes in Regression[1]	Changes in Optimal b_i's[1]	Changes in Efficiency Conditions Primarily Due to Changes in:
	- - - - - Experimental Farms - - - -		
X_2, land	-.253049	+.106013	regression and factor price
X_3, labor	+.466826	+.007055	regression
X_4, productive expenses	+.013306	-.012815	
X_6, machinery investment	-.000076	-.000767	
	- - - - - - - - Control Farms - - - - -		
X_2, land	-.306006	+.153258	regression and factor price
X_3, labor	+.425770	+.006332	regression
X_4, productive expenses	-.060812	-.041671	
X_6, machinery investment	-.033862	+.024841	regression and factor price

[1]Changes in regression, i.e., differences between respective b_i's, and changes in optimal b_i's, are presented in absolute terms; (+) or (-) signs indicate the direction of change.

Regarding the Scale of Operations

Since the nature of returns to scale has been indicated for each function, it will suffice at this stage to ascertain what changes, if any, have occurred with respect to the scale of operations. Figures regarding the returns to scale for each of the functions are presented in Table 17. While increases in the scale of operations would seem to be desirable[14] from the standpoint of increasing the efficiency of the operations, in the aggregate, it can readily be seen that there have not been any appreciable changes

TABLE 17

Changes in the Nature of Returns to Scale, Experimental and Control Farms, 1953 - 1958.

	1953	1958	change
Experimental farms	1.14	1.19	.05
Control farms	1.28	1.35	.07

in the scale of operations on either experimental or control farms, over the period 1953-1958.

[14] This assumes that the farms used in fitting the functions were operating under conditions of increasing returns to scale. While statistical evidence was not available to support this contention, the author was of the opinion that the sums of the b_i's for the 1953 and 1958 control functions, taken individually, were significantly greater than one (indicating increasing returns to scale). The author was less certain as to whether or not the sums of the b_i's for the 1953 and 1958 experimental functions, taken individually, were significantly greater than one. Be that as it may, however, it seems reasonably certain that the sums of the b_i's for the 1953 and 1958 experimental functions, taken individually, were not significantly different from the sums of the b_i's for the 1953 and 1958 control functions, respectively. Hence, the author would conclude that the experimental and control farms were operating under conditions of increasing returns to scale. This leads to the further conclusion that increasing the scale of operations would lead to greater efficiency in the use of resources, in the aggregate.

Regarding Changes in Farm Organization

The author clearly believes that, from the standpoint of this study, relative changes in the use of inputs are of considerably greater relevance than are absolute changes in such. However, absolute changes in the use of resources, by input categories, are presented in Table 18, in order to provide the reader with whatever insights might be gleaned from them. Inasmuch as the table is readily understandable, supporting discourse, in great detail, is not necessary.

TABLE 18

Changes in the Usual Organization, Experimental and Control Farms, 1953 - 1958

Input Category	Units	1953	1958	Change
		Experimental Farms		
X_2, land	tillable acres	136.8	148.3	11.5
X_3, labor	months	14.4	16.4	2
X_4, productive expenses	dollars	4388.	4718.	330.
X_6, machinery	dollars	7369.	7439.	70.
X_1, gross income	dollars	13272.	15260.	1988.
		Control Farms		
X_2, land	tillable acres	134.6	156.4	21.8
X_3, labor	months	16	17.2	1.2
X_4, productive expenses	dollars	3568.	3405.	-163.
X_6, machinery	dollars	7206.	8309.	1103.
X_1, gross income	dollars	12000.	13211.	1211.

However, the author would draw attention to the fact that the geometric mean amount of productive expenses for the control farms actually decreased over the period studied.

At first glance, this seems almost to be a paradox in that here is a case wherein productive expenses have decreased over the period 1953-1958, during which time farmers were involved in the "price-cost squeeze". In order to understand why productive expenses for the control farms decreased, it was necessary to consider, individually, specific expense items, which comprised the productive expenses input category. It soon became evident that the decrease in productive expenses for the control farms was due, in large measure, to the decreasing importance of livestock as a source of income. For instance, several expenses, namely, feed purchased, livestock expense, beginning inventory value of feeders, feeders purchased, value of beginning clover stands and value of perennials destroyed prior to June 1, all of which are directly chargeable to the livestock enterprise,[15] decreased in importance over the period studied. In addition, there was a marked decrease in custom work expense, which seems to have been related to the fact that machinery investment (geometric mean) increased by $1103. per farm. So it was that decreases in the aforementioned expense items outweighed increases in other ex-

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[15]This holds true except for clover grown and plowed down for soil building purposes.

pense items, which resulted in the overall decrease in productive expenses in the case of the control farms.

The author would further point out that while productive expenses, in the case of the control farms, decreased by $163., in terms of the geometric mean amount, productive expenses, in the case of the experimental farms, increased by $330. The author would relate these changes, in part at least, to changes in the capital investment in livestock in view of the fact that capital investment in livestock decreased by $402. per farm, in the case of the control farms, and increased by $500. per farm in the case of the experimental farms.

CHAPTER V

EFFICIENCY CHANGES AS INDICATED BY TRADITIONAL FARM MANAGEMENT EFFICIENCY INDICATORS

Useful insights regarding the nature of efficiency changes were gained by studying changes in certain farm management efficiency indicators,[1] which are presented in Table 19. While elaborate supporting discourse was deemed unnecessary, in view of the fact that Table 19 is readily understandable, it was deemed important that attention be directed to certain of the more noteworthy insights which it purveys.

Evidence of the fact that the experimental and control farms were reasonably well matched, at the outset, is found in the fact that the 1953 efficiency indicators[2] for the experimental and control farms, taken respectively, were of approximately the same magnitude.[3] In support of the previous statement, notice how closely the net farm income of the 1953 experimental farms ($6486) matched the net farm

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[1]See Appendix D, pp. 96-97 where the procedures followed in computing certain traditional farm management efficiency indicators are presented.

[2]Efficiency indicators are presented in terms of arithmetic averages.

[3]This supports the contention held by Nielson and Crosswhite, op.cit., that "the control samples matched the experimental samples well enough to serve as highly useful check groups".

income of the 1953 control farms ($6450). By merely comparing the other 1953 efficiency indicators for the experimental and control farms, the reader will recognize that such was the case with respect to them also.

On the other hand, the 1958 efficiency indicators for the experimental and control farms were generally not of the same magnitude, indicating differences in the efficiency in the use of resources on the experimental farms relative to the control farms. Inasmuch as efficiency in the use of resources is reflected in net farm income, it would seem that the 1958 experimental farms were operating more efficiently than were the 1958 control farms. For instance, the net farm income of the 1958 experimental farms ($7467) was considerably in excess of the net farm income of the 1958 control farms ($6300). This increase in the efficiency in the use of resources, in the case of the experimental farms over that of the control farms, was exemplified by the fact that in the case of the experimental farms there were significant increases in net farm earnings ($905) and net farm income ($981), whereas, in the case of the control farms, there were actual decreases in net farm earnings (-$340) and in net farm income (-$150).

With respect to such efficiency indicators as net farm earnings, net farm income, gross farm income per tillable

TABLE 19

Changes in Traditional Farm Management Efficiency Indicators, Experimental and Control Farms, 1953 - 1958

Indicator	1953	1958	Change
		- Experimental Farms -	
Net farm earnings	$ 6744	$ 7649	$ 905 (c)(e)
Net farm income	6486	7467	981 (c)(e)
Gross farm income per $100 expense	195	172	-23 (a)
Gross farm income per tillable acre	98	116	18 (a)(e)
Gross farm income per man	10581	13172	2591 (b)(e)
Productive man work units per man	208	225	17
Productive man work units per tillable acre	1.8	2.1	.3(c)(e)
		- Control Farms -	
Net farm earnings	$ 6813	$ 6473	$-340
Net farm income	6450	6300	-150
Gross farm income per $100 expense	188	173	-15 (c)
Gross farm income per tillable acre	87	87	0
Gross farm income per man	9671	11204	1533 (b)
Productive man work units per man	212	247	35 (a)(f)
Productive man work units per tillable acre	2.1	1.9	- .2 (c)

(a) indicates a significant change at the 1 percent level of significance.
(b) indicates a significant change at the 5 percent level of significance.
(c) indicates a significant change at the 10 percent level of significance.
(e) indicates a significant change at the level of significance indicated and significantly more change in the experimental area than in the control area, based upon the author's judgment.
(f) indicates a significant change at the level of significance indicated and significantly more change in the control area than in the experimental area, based upon the author's judgment.

acre, gross farm income per man and productive man work units per tillable acre, there was significantly more change in the case of the experimental farms than there was in the case of the control farms. Only in the case of PMWU's per man (productive man work units per man) was there significantly more change in the case of the control farms than there was in the case of the experimental farms.[4]

On the basis of the insights acquired by studying selected farm management efficiency indicators, it would seem reasonable to conclude that there was a greater increase in the efficiency in the use of resources in the case of the experimental farms than there was in the case of the control farms.[5]

Regarding the nature of efficiency changes over the period 1953-1958, the author would draw attention to the fact

---

[4]While increases in the number of PMWU's per man would seem to be desirable, so far as efficiency in the use of labor is concerned, such is not invariably the case. For instance, the number of PMWU's per man can increase as a result of using too little labor relative to other inputs. By referring to Table 9, it becomes apparent that labor, in the case of the 1958 control farms, was earning high returns ($435.44 per month at the margin), which is evidence of the fact that too little labor was being used relative to other inputs.

[5]Inasmuch as average net farm income actually decreased, over the period 1953-1958, in the case of the control farms, it would appear that resources were being used less efficiently on control farms at the termination of the study than was the case at the outset.

that the conclusion drawn, as a result of studying changes in selected farm management efficiency indicators, was consistent with the conclusion drawn, as a result of studying changes in efficiency as indicated by Cobb-Douglas analysis.

CHAPTER VI

CHANGES IN LAND USE, FERTILIZER AND CROP YIELDS

Inasmuch as land and fertilizer, important factors of production in cash crop farming, are important determinants of yields, which are, in turn, determinants of gross farm income and, more ultimately, net farm income, the author deemed it important that special analysis be undertaken for the purpose of ascertaining changes in land use, fertilizer use and crop yields. While this section generally does not provide insights into the nature of efficiency changes similar to those already acquired, using Cobb-Douglas analysis and selected traditional farm management efficiency indicators, it does provide information regarding changes in land use, fertilizer use, and crop yields, without which an input-output study involving cash-crop farms would be incomplete.

Changes in Land Use

When considering changes in land use, in the aggregate, changes in farm size and ownership status become of interest. Such information is presented in Table 20. Inasmuch as Table 20 is readily understandable, there is no need for extensive supporting discourse; however, the author would draw attention to the fact that farm size, as reflected by the average number of tillable acres operated, increased by significantly more in the case of the control farms than in the case of the experimental farms. In keeping with this increase in farm size, the average number of acres owned increased significantly in both the experimental and control areas.

Foremost among the changes in land use, by various crops, were the highly significant increases in the average acreages of beans and sugar beets and the significant decreases in the average acreages of wheat and hay, as indicated in

TABLE 20

Changes in the Ownership Status of Farm Operators, Experimental and Control Farms, 1953 - 1958

Ownership Status	1953	1958	Changes
		- Experimental Farms -	
Total acres operated	164.8	174.9	10.1
Total acres owned	127.6	141.4	13.8 (c)
Total acres rented	37.2	33.5	-3.7
Tillable acres operated	145.	152.4	7.4
		- Control Farms -	
Total acres operated	185.0	202.2	17.2 (b)
Total acres owned	140.7	155.6	14.9 (b)
Total acres rented	44.3	46.6	2.3
Tillable acres operated	156.4	174.8	18.4 (b)(f)

(b) indicates a significant change at the 5 percent level of significance.
(c) indicates a significant change at the 10 percent level of significance.
(f) indicates a significant change at the level of significance indicated and significantly more change in the control area than in the experimental area, based upon the author's judgment.

Table 21. For instance, the average acreage of beans and sugar beets increased by 27.5 and 111.1 percent, respectively,

in the case of the experimental farms and by 35.5 and 100 percent, respectively, in the case of the control farms. On the other hand, however, the average acreages of wheat and hay decreased by 38 and 64 percent, respectively, in the case of the control farms. Notice that, while the changes in the average acreages of beans, sugar beets, and hay were significant for both the experimental and control farms, the changes in the case of the experimental farms were not significantly greater than those in the case of the control farms, and vice versa. However, the decrease in the average acreage of wheat, in the case of the experimental farms, was significantly greater than the decrease in the average acreage of wheat in the case of the control farms.

Further insights regarding changes in land use, which were deemed to be of lesser import and, hence, were not included in the discourse, can be gained by studying Table 21.

Changes in Fertilizer Use

Changes in fertilizer use are presented in Table 22, in terms of changes in the number of pounds of plant food applied per acre -- a distinctly more meaningful term than changes in the number of pounds of fertilizer applied per acre. In aggregate, the average amount of plant food applied per tillable acre for the whole farm increased by approximately the same amount for both the experimental and control farms. Specifically, there were significant increases in

TABLE 21

Changes in the Average Acreage of Various Crops Grown, by Acres and by Percent of Tillable Acres, Experimental and Control Farms, 1953 - 1958

Crop	1953 Acres	1953 %	1958 Acres	1958 %	Change Acres	Change %	
	- Experimental Farms -						
Beans	49.7	34.3	63.4	41.6	13.7	27.5	(d)
Sugar beets	9.	6.2	19.	12.4	10.	111.1	(d)
Wheat	46.6	32.1	28.9	19.0	-17.7	-38.	(d)(e)
Corn(for grain)	12.	8.3	13.	8.5	1.	8.3	
Oats	11.	7.6	14.	9.2	3.	27.0	(d)
Hay	9.9	6.8	3.6	2.4	-6.3	-64.	(d)
Other	6.8	4.7	10.5	6.9	3.7	54.	(d)
Total tillable acres	145.	100.	152.4	100.	7.4	5.1	
	- Control Farms -						
Beans	50.2	32.1	68.	38.9	17.8	35.5	(d)
Sugar beets	11.	7.0	22.	12.6	11.	100.	(d)
Wheat	34.8	22.2	28.3	16.2	-6.5	-19.	(d)
Corn(for grain)	12.	7.7	9.	5.1	-3.	-25.	(d)(f)
Oats	15.	9.6	16.	9.2	1.	6.7	
Hay	17.2	11.0	6.2	3.5	-11.0	-64.	(d)
Other	16.2	10.4	25.3	14.5	9.1	56.	(d)
Total tillable acres	156.4	100.	174.8	100.	18.4	11.8	(b)(f)

(b) indicates a significant change at the 5 percent level of significance.
(d) indicates a significant change based upon the author's judgment.
(e) indicates significantly more change in the experimental area than in the control area, based upon the author's judgment.
(f) indicates significantly more change in the control area than in the experimental area, based upon the author's judgment.

the average amounts of plant food applied per tillable acre with respect to all crops under consideration except for beans, in the case of the experimental farms, and oats in the case of the control farms. Notice that in the case of the experimental farms there were significantly greater increases in the application of plant food per acre on corn (for grain) and oats than there were in the case of the control farms. On the other hand, however, in the case of the control farms there were significantly greater increases in the application of plant food per acre on beans and sugar beets than there were in the case of the experimental farms.

Changes in Crop Yields

Changes in crop yields are presented in Table 23. Notice that for both the experimental and control farms, the average yields of sugar beets, wheat, and oats increased, whereas, the average yields of beans and corn (for grain) decreased over the period 1953-1958. Inasmuch as the average amount of plant food, applied per acre on various crops, increased in all cases, it seems reasonable to have expected that crop yields would also have increased in accordance with the increased plant food applications. But why was this expectation not realized with respect to bean and corn (for grain) yields? While there is no obvious answer to this question, the author would postulate that the decreases in the average yields of beans and corn (for grain) might have been due to a combination of weather conditions, which in 1953 were favorable to bean and corn production, resulting

TABLE 22

Changes in the Application of Plant Food per Acre on Various Crops, Experimental and Control Farms, 1953 - 1958

Pounds of Plant Food per Acre on:	1953	1958	Change
	- Experimental Farms-		
Beans	79.9	93.8	13.9
Sugar beets	192.1	301.2	109.1 (d)
Wheat	109.8	193.1	84.0 (d)
Corn (for grain)	88.1	161.8	73.7 (d)(e)
Oats	84.9	126.0	41.3 (d) (e)
Pounds of plant food per tillable acre, whole farm	93.0	144.5	51.5 (d)
	- Control Farms -		
Beans	36.1	60.9	24.8 (d)(f)
Sugar beets	103.0	257.9	154.9 (d)(f)
Wheat	88.0	148.2	60.2 (d)
Corn (for grain)	67.0	116.0	49.0 (d)
Oats	74.8	95.0	20.2
Pounds of plant food per tillable acre, whole farm	53.2	102.1	48.9 (d)

(d) indicates a significant change, based upon the author's judgment.
(e) indicates significantly more change in the experimental area than in the control area, based upon the author's judgment.
(f) indicates significantly more change in the control area than in the experimental area, based upon the author's judgment.

in high yields, but in 1958 were unfavorable to bean and corn production, resulting in somewhat lower yields.

Notice, that in the case of the experimental farms, there were significantly greater increases in the average yields of oats and hay than there were in the case of the control farms. However, it should be recognized that this

TABLE 23

Changes in Crop Yields per Acre,
Experimental and Control Farms, 1953 - 1958

Crop	Units	1953	1958	Change
		- Experimental Farms -		
Beans	bushels	23.	19.	-4.
Sugar beets	tons	13.8	19.6	5.8 (d)
Wheat	bushels	36.	62.	26. (d)
Corn (for grain)	bushels	81.	66.	-15.
Oats	bushels	56.	110.	54. (d)(e)
Hay (alfalfa)	tons	1.9	3.0	1.1 (d)(e)
		- Control Farms -		
Beans	bushels	22.	20.	-2.
Sugar beets	tons	11.9	16.6	4.7 (d)
Wheat	bushels	38.	57.	19. (d)
Corn (for grain)	bushels	72.	58.	-14.
Oats	bushels	56.	88.	32. (d)
Hay (alfalfa)	tons	3.0	2.0	-1.0 (d)

(d) indicates a significant change based upon the author's judgment.
(e) indicates significantly more change in the experimental area than in the control area, based upon the author's judgment.

significantly greater increase in the average yield of hay, in the case of the experimental farms over that of the control farms, was not very important in that the average acreage of hay grown, on both the experimental and control farms, decreased very significantly over the period 1953 - 1958.

CHAPTER VII

CONCLUDING STATEMENTS

Ample evidence is now available to support concluding statements as to whether or not there was a greater increase in the efficiency in the use of resources in the case of the experimental farms (attributable to the Michigan township extension program) than there was in the case of the control farms. Without reiterating, step by step, what has already been stated explicitly in Chapter IV (see especially Tables 14, 15, and 17 and the supporting discourse which applies in each case), the author would conclude, on the basis of evidence provided by Cobb-Douglas analysis, that there was, in the case of the experimental farms, a significantly greater increase in the efficiency in the use of resources than there was in the case of the control farms.

Inasmuch as both the experimental and control farms, at the outset, were operating under conditions of increasing returns to scale, increases in the efficiency in the use of resources could have been achieved by increasing the scale of operations (i.e., by increasing the use of resources in the very proportions in which they were being used). However, since the analysis bears out that there were no appreciable changes in the scale of operations of either the experimental or the control farms, over the period 1953-1958, it becomes evident that the significant increase in the efficiency in the use of resources, in the case of the experimental farms over that of the control farms was not due to changes in the scale of operation. Thus, the author would conclude that the Michigan township extension program was instrumental in increasing the efficiency with which resources were used, in the case of the experimental farms over that of the control farms, by virtue of the fact that the township extension agent was effectual in advising farmers as to what changes in farm organization could be effected in order to cause resources to be used more nearly in the proper proportions relative to each other.

On the basis of insights gained by studying selected farm management efficiency indicators (see Table 19 and the supporting discourse which applies), the author would conclude that there was a greater increase in the efficiency in the use of resources in the case of the experimental farms than there was in the case of the control farms. Notice that this conclusion is clearly consistent with the conclusion drawn as a result of studying changes in efficiency as indicated by Cobb-Douglas analysis. Thus, all the evidence supports the conclusion that the Michigan township extension program was more effective in increasing the efficiency with which resources were used on cash crop farms in Denmark township than was the traditional county extension program.

APPENDICES

APPENDIX A

PROCEDURES FOLLOWED IN PREPARING THE DATA FOR COBB-DOUGLAS ANALYSIS

Summary Sheet for Cobb-Douglas Analysis
Farm no._____ Area_____
(1) Tillable acres______

Hay and pasture inventory
Total beginning value of perennials and 2nd year clover______
Minus prop. credit for perennials destroyed (-)____
Sub total______
Plus machinery hired for land reclamation ______
Plus value of perennial seed purchase and used ______
Plus value of excessive lime or fertilizer investment ______
Total forage investment ______
Beginning value of one year clover stands _________) transfer to
Beginning value of perennials destroyed before June 1 _________) expenses

Livestock inventory and balance
Beginning inventory of breeding stock ______________ Ending inventory______
Plus breeding livestock purchased ______________ Beginning inventory plus purchases ______
Beginning inventory plus purchases (total) ______________
Increase or decrease (circle one) ______
Feeders on hand_________) transfer
Feeders purchased_______) to expenses page.

Livestock investment
Beginning inventory of breeding stock __________
Plus total prop. cost of breeding stock __________
____
Minus prop. credit of breeding livestock sold __________
__________ Total breeding livestock investment
Total forage investment
(2) Total livestock - forage investment

Machinery investment
Auction value January 1, 1953 (or January 1, 1958) __________
Plus prop. additions __________
____
Minus prop. deductions (-)______
____
(3) Total machinery investment __________

Gross income

Total value of family living furnished by farm ______
Total cash receipts ______
Livestock investment, increase or decrease ______

Feed and seed investment, increase or decrease ______
(4) Total gross income ______
(5) Total months of labor ______

Labor ______

Productive expenses

Feed purchased ______
Seeds and plants purchased annual ______
Custom work or machinery hired ______
Supplies purchased ______
Gas and oil for farm use (less refund) ______
Livestock expense ______
Electricity (Farm share) ______
Telephone (Farm share) ______
Baby Chicks purchased ______
Automobile (Farm share) ______
Truck upkeep (Farm share) ______
Other productive expenses ______
Beginning inventory of feeders and/or broilers ______
Feeders purchased ______
Beginning value of clover stands ______
Beginning value of perennials destroyed before June 1 ______
(6) Total productive expenses ______

(7) Fertilizer expense ______

Final summary

(1) Tillable acres (X_2) ______

(2) Total livestock-forage investment (X_5) ______

(3) Total machinery investment (X_6) ______

(4) Total gross income (X_1) ______

(5) Total months of labor (X_3) ______

(6) Total productive expenses (X_4) ______

(7) Fertilizer expense (X_7) ______

Hay-Pasture Evaluation, 1958[1]

The values used in computing the investment in perennial forage stands were based on the estimated per acre cost of establishing the stands. Adjustments were made to take into account the quality and age of the stand as shown below in Table 24.

TABLE 24

Hay-Pasture Evaluation, 1958

1) For perennials: Condition of stand

Year	Excellent	Good	Fair	Poor
1st	$33	$33	$26	$19
2nd	33	26	19	12
3rd	33	19	12	12
4th	26	19	12	5
5-6th	19	19	12	5
7-8th	19	12	12	5

2) For reed canary grass:

Year	Excellent	Good	Fair	Poor
1st	$17.50	$17.50	$16.50	$10.00

3) For annuals:

Crop	Excellent	Good	Fair	Poor
Red clover	$24.50	$24.50	$23.50	$10.00
Red clover-sweet clover mixture	24.00	24.00	23.00	10.00
June clover-sweet clover mixture	24.00	24.00	23.00	10.00
Sweet clover	23.50	23.50	22.50	10.00
Mammoth clover	23.50	20.00	19.00	10.00
Sudan grass	36.00	36.00	35.00	10.00
Rye	26.00	26.00	25.00	10.00
Oats	30.50	30.50	25.00	10.00

[1]The values used in the 1958 hay-pasture evaluation were worked out by the author with assistance from Professor C.R. Hoglund, Department of Agricultural Economics, Michigan State University. Professor Hoglund suggested that, because of increasing costs, (namely, machine cost, gas, oil, etc.) the values used in the 1953 hay-pasture evaluation be adjusted downward by five dollars per acre, which recommendation was followed herein.

Ordinary rough pasture was valued at five dollars per acre. Other pasture was valued in accordance with the quality of the stand, using the chart for the 1958 hay-pasture evaluation.

Calculating Proportional Credits for Perennials Destroyed

The following criteria were used in calculating proportional credits for perennials destroyed:

1. Proportional credit was computed only if the stand of perennials was destroyed (plowed down) on June 1 or thereafter.
2. The beginning inventory value of alfalfa-brome was counted as an expense, if plowed down prior to June.
3. Proportional credit was computed, if alfalfa-brome was plowed down after June.1. In addition, the beginning inventory value of the stand minus the proportional credit was counted as an expense.
4. Proportional credit was computed for alfalfa-brome plowed down in August or September for wheat, even if it was clipped or pastured during the summer.
5. Proportional credit was computed for any good stand of pasture which was plowed down for corn or oats in the spring.
6. If a worthless stand of hay or pasture was plowed down, proportional credit was not computed.

7. Proportional credit was not computed for clover destroyed. First year clover was counted as an expense. Second year clover was considered as an investment at five dollars per acre.
8. Biennial seeding such as June clover, sweet clover, etc., was considered as an expense, except if seeded in a perennial mixture.

Calculating Proportional Costs and Credits for Breeding Stock

For the purpose of this study, only dairy cattle were regarded as breeding stock -- the rest were considered as feeders for which no proportional costs or credits were calculated. The procedures followed are outlined below. If breeding stock were purchased (proportional cost) or sold (proportional credit) in:

January, multiply value paid or received by 1.	
February	.92
March	.83
April	.75
May	.67
June	.58
July	.5
August	.42
September	.33
October	.25
November	.17
December	.08

in order to determine the proportional cost or proportional credit.

Calculating Proportional Additions and Deductions for Machinery Bought and Sold

The very same method was used in this case as was used in calculating proportional costs and credits for breeding stock purchased and sold.

APPENDIX B

STATISTICAL TESTS TO BE USED WHEN STUDYING REGRESSION COEFFICIENTS, INDIVIDUALLY AS WELL AS IN AGGREGATE

A "t" Test Employed to Determine Whether or Not Significant Differences Were Existent Between the Regression Coefficients of the Experimental and Control Areas

The statistic used, which has a "t" distribution, is given below:

$$t = \frac{b_i - b_i'}{Sp\sqrt{a_{ii} + a'_{ii}}} \qquad B\ (1)$$

where:

b_i = the general expression for a regression coefficient of the experimental function.

b_i' = the general expression for the corresponding regression coefficient of the control function.

Sp is the pooled variance, derived from the following equation:

$$Sp = \sqrt{\frac{(N-1)s^2 + (N^1-1)s'^2}{(N-1) + (N^1-1)}}$$

where:

N = number of observations in the experimental sample.

N^1 = number of observations in the control sample.

$s^2 = \frac{\Sigma(yi-\bar{y})^2}{N-1}$ = estimated variance in gross income for the experimental sample where: y_i = actual gross income

$\bar{y}$ = arithmetic mean of gross income

$s'^2 = \frac{\Sigma(y_i-\bar{y})^2}{N' - 1}$ = estimated variance in gross income for the control sample.

a_{ii} indicates the diagonal element of the inverse matrix of the experimental observations. a'_{ii} indicates the diagonal element for the control observations. The only difference between a_{ii} and a'_{ii} is in the matrix Z (due to different observations). Hence, it will suffice to demonstrate the way in which either a_{ii} or a'_{ii} is obtained. The author has chosen to obtain a_{ii}. Consider the Z matrix, defined below, whose element is an observation on an independent variable, z_{ij}, i.e., the ith observation on the jth row:

$$Z = \begin{pmatrix} 1 & z_{11} & z_{12} & z_{13} & z_{14} & z_{15} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & z_{N1} & z_{N2} & z_{N3} & z_{N4} & z_{N5} \end{pmatrix}$$

Notice that five independent variables are involved. Now, $Z'Z$ is the sample moment matrix, the inverse of which is denoted by: $(Z'Z)^{-1}$. In the inverse matrix, next consider the diagonal element, a_{ii}, for $i = 1 \ldots 6$. Pick out the

a_{ii} value which corresponds to the particular regression coefficient which is being tested. The final step is to substitute these derived values in equation B (1) which has the "t" distribution with N + N' -2 degrees of freedom.

Two necessary assumptions which must be met in order to use the above form of the "t" test are: 1) the assumption of independence between experimental and control samples and 2) the assumption that the variance associated with the experimental variables is the same size as the variance associated with the control variables.

An "F" Test Employed to Determine Whether Or Not the Sum of the Regression Coefficients is Significantly Different From One

The statistic used which has an "F" distribution is shown below:

$$F = \frac{(c'b-1\ [c'(Z'Z)^{-1}c]\ (c'b-1)}{\frac{1}{N-6}\ \cdot V'V}$$, with 1 and N-6 degrees of freedom.

where:

$(c'b-1) = [(b_2 + b_3 + b_4 + b_5 + b_6) -1]$ $(Z'Z)^{-1}$ = inverse matrix.

$$C = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 1 \\ \cdot \\ \cdot \\ 1 \end{pmatrix}$$

$c'(Z'Z)^{-1}c$ = sum of squares and sums of cross products of the independent variables.

N = number of farms in the sample.

N-6 = number of degrees of freedom for 5 independent variables.

$\hat{V}'\hat{V}$ = sum of squared residuals = Σ(actual income-predicted income)^2

The hypothesis is stated as: $c'B = 1$. If "F" calculated were greater than "F" in the tables for 1 and N-6 degrees of freedom, at the particular level of significance chosen, the hypothesis would be rejected.

APPENDIX C

OBSERVATIONS USED IN FITTING THE FUNCTIONS, SUMMARIZED BY OUTPUT AND INPUT CATEGORIES

TABLE 25

Observations Used in Fitting the Experimental Function, 1953

Variable Farm No.	Land (X_2)	Labor (X_3)	Productive Expenses (X_4)	Livestock-Forage (X_5)	Machinery Investment (X_6)	Gross Income (X_1)
401	95.	15.6	$4850	$ 1	$10423	$12225
402	288.	27.	8157	754	9856	31285
404	114.	18.	4700	1	8037	9613
405	76.	21.	1959	180	3402	6581
406	74.	6.7	4268	1	2267	11458
407	343.	33.9	17195	1120	20930	40984
410	256.	18.	6577	1	15753	20672
411	91.	16.	5391	1	5998	9020
415	170.	15.	3308	531	7460	12358
416	95.	13.	2348	1	1975	7458
417	120.5	10.6	4750	1	10951	17759
419	70.6	10.	3384	1	5999	9165
422	255.	24.4	10205	840	6322	29331
423	176.	13.3	2824	1	7733	18601
426	140.	28.8	5160	4565	10933	16047
427	90.	8.	2626	1	4548	7224
428	156.	18.4	4572	1	9433	11521
430	133.	9.	2776	1	6480	8461
432	203.	17.	3730	554	5596	13612
433	190.	9.	3284	1	11899	16344
435	101.	8.	2196	1	6455	6023
437	141.	11.	4963	1	7262	14157
438	184.	29.	9029	4054	18118	26126
439	80.	6.	4057	1	6443	9484

TABLE 26

Observations Used in Fitting the Control Function, 1953

Variable Farm No.	Land (X_2)	Labor (X_3)	Productive Expenses (X_4)	Livestock-Forage (X_5)	Machinery Investment (X_6)	Gross Income (X_1)
501	105.	10.	$3548	$1661	$ 3486	$ 5801
504	106.6	12.	2309	1	2401	7514
506	70.	15.6	3141	434	3819	4739
509	142.	17.7	4624	1458	5478	13555
510	182.	14.	3467	1	9817	13464
511	233.	16.3	5232	4576	9118	26389
512	105.	14.	2655	2175	4262	8334
514	95.	5.	1680	1	3022	5347
516	167.	20.	3897	2447	11663	14096
517	87.5	17.	3794	2955	5141	7416
518	138.	10.8	8008	466	8791	19200
519	132.	25.6	2463	1	7539	12232
520	221.	15.7	8054	1	14494	23704
521	70.	13.	677	1	5108	3784
523	277.	36.8	6942	1	15974	24850
524	150.	14.4	5295	812	5859	12697
525	101.	24.8	3593	1037	9233	13533
526	113.	8.3	2072	1	8766	8058
527	66.5	8.	1274	1	4446	5578
528	154.	13.	5250	1	4916	12532
530	150.	21.	2836	1	9625	15369
531	139.	26.3	4485	336	10509	15687
532	184.	22.6	6654	1	10550	22109
533	75.	15.	2015	1	5944	10903
534	166.	18.3	3532	1	19258	14520
537	186.5	21.5	5565	1	7931	16188
538	367.	35.	8772	1	15164	43884

TABLE 27

Observations Used in Fitting the Experimental Function, 1958

Variable / Farm No.	Land (X_2)	Labor (X_3)	Productive Expenses (X_4)	Livestock-Forage (X_5)	Machinery Investment (X_6)	Gross Income (X_1)
401	95.	7.5	$3514	$ 740	$ 6033	$11869
402	405.	48.9	9853	1	9809	45372
404	122.	18.	3213	57	6920	14134
405	132.	19.	3527	88	3456	10770
406	150.	20.1	15988	1	5129	29464
407	251.	33.1	20663	878	11202	48770
410	238.	21.7	4961	46	17107	21423
411	93.	14.2	4103	1	6719	13717
415	184.	19.6	3702	1	9645	12480
416	117	10.	2259	20	3563	8331
417	185.	20.	5256	1	14210	21256
419	75.	14.4	4043	65	6691	12297
422	298	34.	8321	1	13040	36773
423	163.	15.1	3322	99	10811	15006
426	157.	22.9	5075	3304	24333	17499
427	136.	18.	6137	230	7437	14400
428	105.	14.	4415	1	5084	9271
430	192.	13.2	2960	132	3508	14271
432	175.	12.	4872	752	7035	9479
433	73.	7.7	1847	1	4963	7319
435	101.	9.8	2490	1	7262	4729
437	146.	13.	3499	1	6021	10556
438	283.	20.	15551	8205	16081	52163
439	74.	10.7	2288	1	2425	7894

TABLE 28

Observations Used in Fitting the Control Function, 1958

Variable / Farm No.	Land (X_2)	Labor (X_3)	Productive Expenses (X_4)	Livestock-Forage (X_5)	Machinery Investment (X_6)	Gross Income (X_1)
501	175.	16.4	$3425	$1929	$ 3297	$ 8604
504	108.	7.7	2611	1	23109	8466
506	68.	15.7	2253	137	10722	8643
509	155.	26.	2171	1	5180	13436
510	150.	17.	3774	96	10125	11286
511	155.	19.6	2785	1973	5329	13823
512	106.	11.6	2986	1	10375	9794
514	94.	14.	1592	414	4902	5738
516	159.	27.7	6485	6220	12003	16638
517	144.	18.1	4486	291	5330	11852
518	237.	12.5	2543	579	6426	9653
519	115.	14.3	2378	75	10482	12301
520	198.	18.6	7151	1	9068	19575
521	144.	13.3	1712	1	6629	7590
523	276.	27.3	5508	1	10359	20875
524	182.	15.4	5742	271	5396	12885
525	112.	18.7	4491	403	10088	21869
526	150.	15.	3084	1	6352	10783
527	117.	8.5	2280	1	7341	7548
528	168.	10.9	2419	1	7283	11858
530	152.	27.7	2923	1	11471	18662
531	164.	19.8	2375	37	6686	15034
532	186.	22.9	5054	1	7403	14199
533	72.	14.6	1944	1	5262	8939
534	487.	29.0	7463	34	17470	40536
537	225.	19.0	5381	1	12808	23068
538	355.	33.2	7475	1	17508	38262

APPENDIX D

PROCEDURES FOLLOWED IN COMPUTING CERTAIN TRADITIONAL FARM MANAGEMENT EFFICIENCY INDICATORS

COMPUTING MEASURES OF FARM EARNINGS

1. Total cash farm receipts			$______
2. Livestock purchases		$______	
3. Inventory changes: Feed and crops	$_____		
Livestock	_____		
Total inventory change	_____		
4. GROSS FARM INCOME (1-2+ or - 3			______
5. Value of farm products used at home		______	
6. TOTAL VALUE OF FARM PRODUCTION (4 + 5)			______
7. Total cash farm expenses		______	
8. Depreciation: Machinery	_____		
Buildings	_____		
Total depreciation		______	
9. Total cash expenses and depreciation (7 + 8)			______
10. NET FARM INCOME (4 - 9)			______
11. NET FARM EARNINGS (6 - 9)			______

COMPUTING MEASURES OF GROSS FARM INCOME

1. Gross farm income	______	
2. Expenses and depreciation ÷ $100	______	
3. Tillable acres	______	
4. Number of men	______	
5. GROSS FARM INCOME:		
a) PER $100 EXPENSES (1 ÷ 2)		______
b) PER TILLABLE ACRE (1 ÷ 3)		______
c) PER MAN (1 ÷ 4)		______

COMPUTING MAN WORK UNITS

TABLE 29

Chart Used in Determining the Number of Productive man Work Units

Crops	Acres	PMWU Factor	PMWU Total
Corn, silage		1.5	
Corn, grain		1.0	
Oats		.6	
Wheat		.6	
Sugar beets		5.0	
Soybeans		.8	
Alfalfa hay		.7	
Other hay		.7	
Grass or legume silage		.7	
Total, crops		---	

Livestock	Number	Factor	Total
Dairy cows		10.0	
Bulls		8.0	
Calves and heifers		2.0	
Beef cows		2.0	
Feeders		1.5	
Litters		3.0	
Hogs bought		.25	
Ewes and rams		.5	
Hens		.18	
Chicks bought		.06	
Turkeys		.3	
Total, livestock		---	

Total PMWU, crops and livestock ____________

PMWU per man ____________

PMWU per tillable acre ____________

BIBLIOGRAPHY

Beringer, C., A Method of Estimating Marginal Value Productivities of Input and Investment Categories on Multiple Enterprise Farms, (unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, 1955).

______________, "Problems in Finding a Method of Estimate Marginal Value Productivities for Input and Investment Categories on Multiple Enterprise Farms", Resource Productivity, Returns to Scale and Farm Size, (edited by Heady, Johnson and Hardin, Ames, Iowa: Iowa State College Press, 1956).

Bradford, L.A., and Johnson, G.L., Farm Management Analysis, (New York: John Wiley and Sons, Inc., 1953), p. 144.

Brooke, D.M., Marginal Value Productivities of Inputs on Cash Crop Farms in the Thumb and Saginaw Valley Area of Michigan, 1957, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State University, 1958).

Dixon, W., and Massey, F., Introduction to Statistical Analysis, (second edition, New York: McGraw-Hill Book Co., Inc., 1957), p. 115.

Drake, L.S., 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).

Eicher, C., The Use of Cobb-Douglas Analysis in Evaluating the Michigan Township Extension Program, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State University, 1956).

Ezekiel, M., Methods of Correlation Analysis, (second edition, New York: John Wiley and Sons, Inc., 1949), p. 502.

Farm Labor, Agricultural Marketing Service, United States Department of Agriculture, (Washington, D.C.: Government Printing Office, January, 1959).

"Instructions for Interviewers - Michigan Township Extension Research" (unpublished paper, Department of Agricultural Economics, Michigan State College, 1953).

Johnson, G.L., "Classification and Accounting Problems in Fitting Production Functions to Farm Record and Survey Data", Resource Productivity, Returns to Scale and Farm Size, (edited by Heady, Johnson and Hardin, Ames, Iowa: Iowa State College Press, 1956), pp. 90-91

Nielson, J., "Farm Planning Township Style", (unpublished paper, Department of Agricultural Economics, Michigan State College, 1954), p. 5.

____________, "Notes on the Research Design and Procedures for Evaluating the Township Extension Program", (unpublished document, Department of Agricultural Economics, Michigan State University, January, 1956).

____________, and Crosswhite, W., "The Township Extension Experiment - What Happened During the First Two Years", "Technical Bulletin 266, Michigan State University, Agricultural Experiment Station, February, 1958), p. 9.

"Proposal to the Kellogg Foundation for an Experimental Intensive Extension Program in Five Townships in Michigan", (prepared by the Cooperative Extension Service, Michigan State College, 1953), p. 2.

Resource Productivity, Returns to Scale and Farm Size, (edited by Heady, Johnson and Hardin, Ames, Iowa: Iowa State College Press, 1956).

Tintner, G., "A Note on the Derivation of Production Functions from Farm Account Records", Econometrica, Vol. 12, No. 1, (January, 1944), pp. 26-34.

____________, and Brownlee, O., "Production Functions Derived from Farm Records", Journal of Farm Economics, Vol. 26, (August, 1944), pp. 566-571.

Toon, T., Marginal Value Productivities of Inputs, Investments and Expenditures on Upland Grayson County Farms During 1951, (unpublished M.S. Thesis, University of Kentucky, 1952).

Trant, G.I., A Technique of Adjusting Marginal Value Productivity Estimates for Changing Prices, (unpublished M.S. Thesis, Michigan State College, 1954).

Wagley, R., The Marginal Productivities of Investment and Expenditures, Selected Ingham County Farms, 1952, (unpublished M.S. Thesis, Department of Agricultural Economics, Michigan State College, 1953).

retd May 6