LABOR AND MECHANIZATION ON MANITOBA FARMS

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ABSTRACT

The main objectives of this study were to determine the economic relationships which exist between labor and machines on farms in two samples drawn from Manitoba.

To facilitate this end, multiple regression analysis and the Cobb-Douglas production function were used to estimate the productivity of resources employed in producing the gross farm income.

The sample of farms used in the micro analysis consisted of 44 farms in the Carman area and 52 farms in the Western area, around Hamiota. These two widely separated areas give an illustrative view of a large part of the farming industry in Manitoba.

The estimated productivity of land in the Carman area is very low. Since it cost 38% more to possess land in the Carman area than in the Western area, land in the Carman area appears to be over-priced.

Fertilizer appears to be used to excess in the Western area in light of its estimated productivity. The methods and techniques of farming in this area require less fertilizer than in the Carman area where more fertilizer could be profitably utilized.

The two factors of production, labor and machinery, were found to be in imbalance. The balance, or least-cost combination of these factors is affected by the area location, the techniques employed in the farming operation, as well as the price and availability of the other factors of production.

In the Carman area more labor could be profitably employed, relative to machinery, while the opposite situation is true in the Western area.

While the factors of labor and machinery are not at the point of least cost combination, the imbalance is relatively small. Any substantial alteration of one factor would require a large compensatory alteration of the other factor. That is, a significant removal of labor from the agricultural sector would require a major lowering of the machinery cost factor of production, if the agricultural sector were to maintain or strengthen its position.

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CHAPTER I

INTRODUCTION

Is the age approaching when labor will no longer be a significant factor in farm production? Will radio controlled machines take over completely in a semi-robot environment? Many economists, and some farmers, at the present time believe that there is a redundancy of labor on even the best organized farms in Manitoba. Some economists, and many farmers, however, agree that it would be possible to maintain or increase production from the agricultural sector of Manitoba with less labor, but they point to restraining factors such as spiralling machine costs and the scarcity and expense of other important factors of production.

Because of the nature of the agricultural profession a farmer's time is worth what he makes it. If he attempted to till the soil using methods of 100 years ago his time would be worth very little. Conversly, if he purchased excessive amounts of high capacity machinery his time might be very valuable, but he would likely go bankrupt paying for the machines. This is illustrative of the law of variable proportions. The combination which the farmer employs is usually dictated by the supply available, and the prices of the relevant factors.

The use of machinery is, of course, the most effective way of increasing output per worker. For thousands of years, the principal tools of farming were the crooked sticks used as ploughs and hoes, and the reaphook. The low productivity of labor is demonstrated in the Biblical story of Ruth gleaning in the fields of Boaz.

"So she gleaned in the field until even, and beat out that she had gleaned: and it was an ephah of barley."[1]

The gleaners, of course, would not gather as much produce as the main harvestors, but this does give some indication of the general productivity of labor at this time.

It is estimated that a man could "plow" an acre a month with a crooked stick. With a modern spading fork he can do the same amount of ploughing in eight days; with a team and a twelve inch plough in one day; with a three plow tractor in one hour.

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[1]Norman E. Lee, Harvests and Harvesting Through the Ages, Cambridge at the University Press 1960, p. 61. An ephah is about one peck.

Little changes were made until about one hundred years ago. Many of our grandfathers used the tools of Boaz. During the 1830's the mechanical reaper and steel plough heralded a revolution. Production per worker increased about 140% from the American Civil War to World War II and has further increased about 50% since 1940.

As the output per worker increases, the value of the worker's time tends to increase. There is a close correlation over time between the productivity of an hour's labor and the value of an hour's labor. There is also the implication of a close relationship between the cost of the machine per hour and the value of the labor per hour.

The value of Ruth's labor with primitive tools would be very meager. The purpose of this study is to study the interrelationships that exist between the productivity of the machine, the cost of the machine and the value of labor.

In the most primitive society the entire population is engaged in farming-- wresting a living from the land either by cultivating the soil or by hunting. As the society advances usually it is because some type of machine or innovation makes it possible for one man to produce enough food for more than just himself, freeing men to turn their talents to producing other goods and services. Thus there is a direct connection between the tools used by the men of the soil and the standard of living. As society advances further, these other men produce goods and services to satisfy wants instead of needs and the standard of living is gradually raised.

To try to evaluate the present movement from the farm to the city and to attempt to judge whether it is likely to slow down or to accelerate we will take a quick glance at history to try to ascertain the meta-physical aspects.

Notice the following quotation from Lee's history of harvesting:

"It is a strange fact that, although the Romans had large wheat farms, suitable for the developement of farm machines, in their great empire, they did not make use of such machines to any great extent. This is no doubt another example of 'the blind spot in the Roman technical eye', because of the great numbers of slaves available for farm labour."[2]

The Romans did make little use of a reaping machine described by Pliny (A.D. 23-79). Pliny's reaper pushed from behind by an ox merely cut off the heads of the wheat, leaving the straw standing. This was a disadvantage in countries where the straw was valuable as fodder. The sowing plough had been known in the ancient world for centuries and was used extensively in Babylonia. The Romans were such splendid engineers that they could have improved these two inventions and spread them far and wide through their vast empire. The reason they did not was probably because of the plentiful supply of slave labor.

Any attenpt in the present day and age to replace labor with excessive amounts of excessively expensive machinery likewise will probably be unsuccessful.

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[2] Lee, op. cit., p. 81.

In 1826, Patrick Bell in Britain invented a reaping machine. It was not enough that the reaper had been invented and had proven to be a satisfactory substitute for labor. The invention might have been shelved as previous inventions were during the Roman era if the crop could have been satisfactorily harvested by other means. As long as vast quantities of cheap labor were available there was little incentive to mechanize. Old and tried methods have usually been retained until an emergency forces a change.

An emergency appeared in the form of civil war in the U.S.A. Thousands of farmers there found it necessary to purchase the new machines or see their crops rot in the fields. Before 1861, many thousands of farmers had bought reaper machines but tens of thousands of other farmers had preferred to go on reaping by hand, especially when they had four or five sturdy sons to help them. To reap by hand they used a device called the cradle which was an improvement on the scythe and cost very little compared with the reaping machine. Thousands of reaping machines pouring forth from the factories of the north proved to be for the north what the slave was for the south. On April 9, 1865 the starving southern armies surrendered.

First oil tractors to be used to replace horses in the fields were built in Britain in 1897. The demand for these machines remained small until the outbreak of the war of 1914-18. German U-boats cut off much of Britain's supply of food. To counter-act this, Britain initiated programs to plough up thousands of acres of grass land. It was impossible to get enough horses to pull the ploughs needed for the task. The only solution was to get a large number of the new oil tractors. The British government hastily placed with Henry Ford an order for 5000 Fordson tractors at a cost of $700 each. Most of these tractors were driven by women to release men for the British Army.

The war of 1914-18 did for the oil tractor what the American Civil War had done for the reaper in the U.S.A .

The first permanent and successful threshing machine was invented by a Scottish millwright called Andrew Meikle in 1788. The new machines were in common use in Scotland after 1800 and their use spread through England and Ireland.

Farming had been booming in England during the Napoleonic wars but after 1815, with the coming of peace, laborers found it hard to get work. In 1831, at the beginning of the threshing season, four hundred laborers went from farm to farm breaking threshing machines. They were even encouraged by some magistrates who strongly criticized the new machines. One result of the riots was to hold up the advance of new farming innovations in Britian.

The idea of the combine harvestor, which was the last innovation to be adopted here on the prairies, has been around for almost as long as the reaper.

"In 1836 E. Briggs and C.G. Carpenter secured a patent on a four wheel machine with equipment for harvesting and threshing."[3]

The combine didn't gain much popularity in Manitoba during the twenties. The varieties of grain were not

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[3] J. Brownlee Davidson, Agricultural Machinery, John Wiley and Sons Inc. New York, 1931, p. 198.

suitable for 'straight' combining and a satisfactory swather had not yet been introduced. In the 1930's different varieties of new grains were introduced which were more adaptable to combine harvesting and the use of combines became more widespread.

With the outbreak of World War II the shortage of labor brought on an emergency. The Canadian government recognized the value of the combine reaper as a labor saving device and gave preference and allocated factory space and steel towards their manufacture. By this order the Canadian Company, Massey-Harris, became world leaders in the manufacture of these machines--a position they still retain today.

This review of the adoption of farm mechanization helps to give us a perspective of some of the causes and effects of the process.

Changes in the combination of labor and machines in agriculture seems to require two things:

1. The introduction of additional machinery; and

2. A set of conditions that attracts labor to other sectors of the economy.

CHAPTER II

NATURE AND SCOPE

This study will examine the microeconomic aspects of the complement of machines and labor that exists on a sample of Manitoba farms today. The data used were provided by the two farm business associations of the province: The Carman District Farm Business Association and the Western Manitoba Farm Business Association. These two associations co-operate in farm management research with the University of Manitoba. They are situated in widely separated areas, and should at least give a partial indication of conditions which exist on Manitoba farms at the present time.

Farms selected for the analysis were those which earned sixty per-cent or more of their income from field crop production. In the Carman area forty four farms were in this group and fifty two from the Western area were in this category.

This provided a total of ninety six farms out of a provincial total of 39,747 or about .24%. Farms in the sample are larger than the provincial average.

The average farm in the Carman sample had 771 acres with 702 acres cultivated, and 91.5% of the cultivated area in crop. The average farm in the Western area had 788 acres with 555 acres cultivated and 71.3% of the cultivated area in crop.

This was in the year 1966. In this year the provincial average farm was 462 acres with 295 acres cultivated and 69% in crop.[4]

A peasant tilling his fields with primitive hand tools has a very low productivity. The value of his labor is meager. The cost of the tools is such that it is not mecessary to insure that they are fully utilized. They could be used only for a few hours per day with no great loss. If the spade suddenly increased in price, then it would become a question of fully utilizing the tool and spreading its fixed cost over more hours. Unless labor was very plentiful,

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[4] Year Book of Manitoba Agriculture, Manitoba Dept. of Agriculture, Winnipeg, Manitoba. 1966.

its value would also increase.

These three things are interrelated:

1. The cost of the machine

2. The productivity of the machine

3. The supply of labor

The value of labor is a function of the supply of labor and the productivity of the machine. It is also a function of the cost of the machine.

The productivity of land is not of prime importance in this study. It is important however, to know the productivity of land and other resources in the over-all picture.

The objectives of this study are:

1. To measure the marginal value productivity of land, labor and capital; and

2. To determine the relationship between machine costs and the value of labor

3. To attempt to identify the role which the other factors of production play in determining the optimum balance in the allocation of marginal product between labor and machinery.

Hypotheses to be tested:

1. There is an optimum balance in the allocation of marginal product between the two factors of production: machinery and labor.

2. This optimum balance in the allocation is affected by the area location, the farming techniques, and the other factors of production.

3. Returns to the land factor of production, which provides for the return of land costs and retirement of capital debt, vary between area location.

4. Optimum application of fertilizer varies between area location, and with farming techniques employed.

These hypotheses are advanced as speculation in explanation of phenomena that exist in agriculture. If there is a redundancy of labor in agriculture the solution lies largely within the industry itself. If however the opposite situation exists the decoction might not be so clear.

There seems to be some disagreement among individuals and organizations as to the nature and the possible solution of the so called 'farm problem'. Some think there is a redundancy of labor on farms and that more migration should therefore take place from the country to the city. Others disagree, and suggest that the problem is more complex. Consider the following quotations:

"The crux of both the poverty problem and the agricultural problem is the tragically low level of productivity of a large proportion of the human and physical resources in the farming industry. Policies must be developed to release underutilized physical resources and to free human beings ensnared in hopeless situations so as to give simultaneously, a new and powerful impetus to rising productivity in the agricultural and industrial sectors. To give the people concerned, and particularly their families, the opportunity of realizing their fullest potential and, at the same time, to place agriculture on a sound commercial basis, will probably require not less than 50% fewer farmers by 1975."[5]

"On the basis of the foregoing definitions and the 1961 Census some 43.4% of Canadian farms are uneconomic (209,000 out of 481,000). The proportions are not greatly different in the east and west--44.2% for the Prairie Provinces and 43.8% for the five eastern provinces."[6]

According to this suggestion, a migration from the agricultural sector would be benefical to both the farm sector and the industrial sector. When a large proportion of the farming population left

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[5] M.W.Menzies, Poverty in Canada, Manitoba Pool Elevators, Winnipeg, 1965. p. 29.

[6] *Ibid.*, p. 31.

the farming sector, each remaining individual should have a larger share of the gross income. When such a large migration entered the industrial sector, the wage price there should be bid down. This should result in lower factor prices for the inputs in the agricultural sector, and so it could hope to reap a double benefit. The general standard of living might improve in both sectors.

However, some economists believe that although agriculture is a declining industry, it is still quite important in the over all picture and the removal of still more labor from this sector is not likely to be benifical. Note the following quotations from an address by Dr. G.A.MacEachern, President of the Agricultural Economics Research Council of Canada:

"Generally speaking Canadian agriculture is healthy. In 1966 over 18 billion dollars were invested in agricultural production. While income from agriculture in 1968 was around $4 billion dollars, a figure I must admit, I cannot conceive of myself.

If we go a step further and take into account the multiplier effect, agriculture contributes 30 per cent of the gross national product in Canada."

"On the aircraft coming down today, I met people who think the only way to solve the farmer's difficulties is to get 60 per cent of them out of agriculture. 60 per cent is a figure popular in the non-farm community for some unknown reason. Even agricultural representatives operating in the Western Provinces in some of the best areas-- some of the most productive at that have said to me, 'You know, when I go out and talk to farmers, I really have a hard time,

because I know they shouldn't be there, but you can't tell then that'.
How can a man be honest with himself and make a contribution to farmers if he feels that way?"
"Let me tell you about some more of these myths: -
Excess farm production, too many farmers, producers outsmarting themselves, the farm problem boils down to too much small acreage, no markets, low prices, objectives in agriculture are not known, and finally problems in agriculture can be solved by national policy. All these ideas are just so much bunkum."
"All I can say is that you should talk to Maritimers. That area provides a good example of what happens when people are moved out quickly. The situation doesn't necessarily improve, in fact they get much worse."[7]

According to Dr. MacEachern's hypothesis the agriculural sector is capable of making a significant contribution to the economy of Canada and the removal of labor from this sector might prevent maximum effort.

What is the actual situation on Manitoba farms? Is ther a physical shortage of labor or does the opposite situation prevail? The following are quotations from the Manager of Winnipeg Employment Committee (Canada Manpower Center) April 1967:

"It is anticipated that, as in past years, there will be a shortage of farm labor."

Another quotation from the Manager's report September 1967 :

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7 G.A.MacEachern, Address to The Annual Staff Conference, 1969 of the New Brunswick Department of Agriculture and Rural Development, January 6, 1969 (Fredericton, New Brunswick), pp. 1 and 3-5.

"Harvesting operations were in full swing and experienced farm hands, qualified to operate farm equipment, in short supply. Labour adjustments were necessary between farmers. A number of female workers were trained to operate harvest combines to help offset the acute farm labour shortage."[8]

It would appear that more labor could be utilized in the agricultural sector. However it must be remembered that a shortage of labor may exist in the micro sample of farms but because of inefficient small farms which under utilize human resources in the aggregate farm situation it is possible for a redundancy of labor to exist at the same time, this under utilized labor being unavailable.

Are farmers rational in the use of labor? Would it not be better for them to mechanize further and use less labor? These are some of the questions which this study seeks to answer.

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[8] Manager's Report, Canada Manpower Center, Winnipeg, Manitoba. September, 1967.

CHAPTER III

THEORETICAL METHODS

"If successive units of one input are added to given quantities of other inputs, a point is eventually reached where the addition to the product per additional unit of input will decline."[9]

Economists refer to this expression as the law of diminishing returns. This relationship forms the basis for the technical expression of the production function.

If the quantity of output is denoted by Y and the quantities of variable production services or factors by $X_1, X_2, \ldots\ldots\ldots\ldots X_n$ then the production function equation can be written as:

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

Other concepts which must be developed are the marginal and average products.

The average product (AP) of an input is defined as the ratio of the total product (TP) to the quantity

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[9] C.E.Bishop, and W.D.Toussaint, Introduction to Agricultural Economic Analysis, John Wily and Sons, Inc., New York, 1958. pp. 35-36.

of input used in producing that amount of product. In terms of the symbols which were previously used, the average product is $\frac{Y_1}{X_1}$.

In terms of symbols, the marginal product is $\frac{\Delta Y_1}{\Delta X_1}$. Thus, the marginal product for a unit of input is the change in the product divided by the change in the input. Another way of describing the marginal product is that it is the rate of change which occurs in total product as the quantity of input increases.

Relationships between total, average, and marginal products are shown in Figure 1. When the total product is increasing at an increasing rate (stage I) marginal product is greater than average product. When total product is increasing at a decreasing rate, marginal product is less than average product (stageII). Here the total product is increasing, and the marginal product is greater than zero.

Stage I is not considered a rational area of production since the marginal product is still greater than the average product. An exception to this rule would exist when the demand for the output of the firm is inelastic at a quantity in stage I. Stage III is an irrational area of production because total product is actually reduced by the addition of more of the variable input.

If the input is very expensive, rational production may not extend beyond the point where MP = AP. However if the input is free, it would be rational to operate right to the point where MP becomes zero.

The production function shows us how to maximize the physical product. Once we have chosen the technical combination of factors and are on our production function the question becomes an economic one of how much of the input to use.

The economic question is to determine the point at which the vaue of the marginal physical product of the input becomes equal to the cost of the input used. Obviously, as long as a production process pays more per additional unit of input than the additional

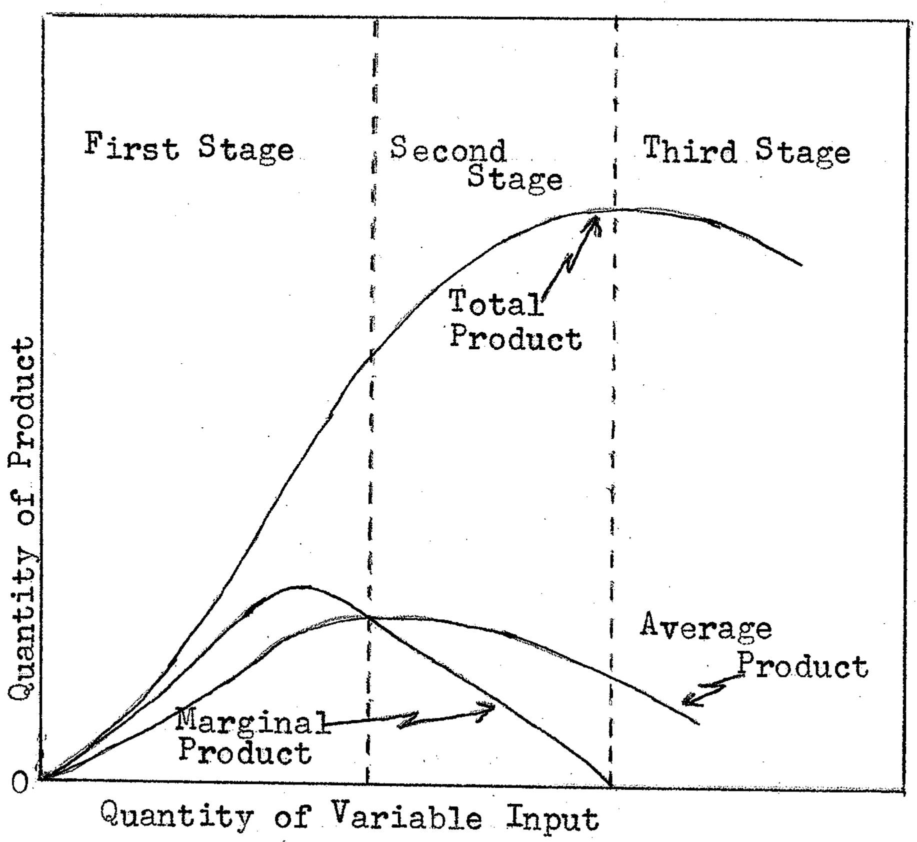

Figure 1 : The Law of Variable Proportions

unit of input costs, it pays to expand production. Equally obvious, assuming a monotonic production function is the conclusion that it does not pay to expand production beyond the point at which the value of the marginal product is equal to the cost of the input. In this area, additional expenditures for the input produce a quantity of product having a smaller value than the increment of input.

Clearly if the prices of the input or product varies or changes from the prices prevailing when the recommendations were made, the recommendations would, in general, no longer be valid. The exception would be in the case where the changes were proportionate. The fundamental condition for the optimum use of the variable X_1 is that the MVP_{x_1} must equal the P_{x_1} . (see Figure 2).

$$MVP_{x_1} = P_{x_1}$$

or

$$\frac{MVP_{x1}}{P_{x1}} = 1$$

The condition for equilibrium in the firm is:

$$\frac{MVP_{x_1}}{P_{x_1}} = \frac{MVP_{x_2}}{P_{x_2}} = \ldots\ldots\ldots\ldots\ldots \frac{MVP_{x_n}}{P_{x_n}} = K, \text{ a constant.}$$

Many inputs such as land are relatively fixed physically for considerable periods of time. Labor on the farm is often supplied solely by the farm operator and his family. Thus labor could also be considered partially fixed. Other inputs such as fertilizer are more easily adjusted to short run changes in prices.

Hicks points out that equilibrium imposes three stability conditions:[10]

1. For the transformation of a factor of production into a product we shall have conditions of diminishing marginal rate of transformation or diminishing marginal product.

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10 J.R.Hicks, Value and Capital, Second Edition, Oxford University Press, Amen House, London, 1957. pp. 86-87.

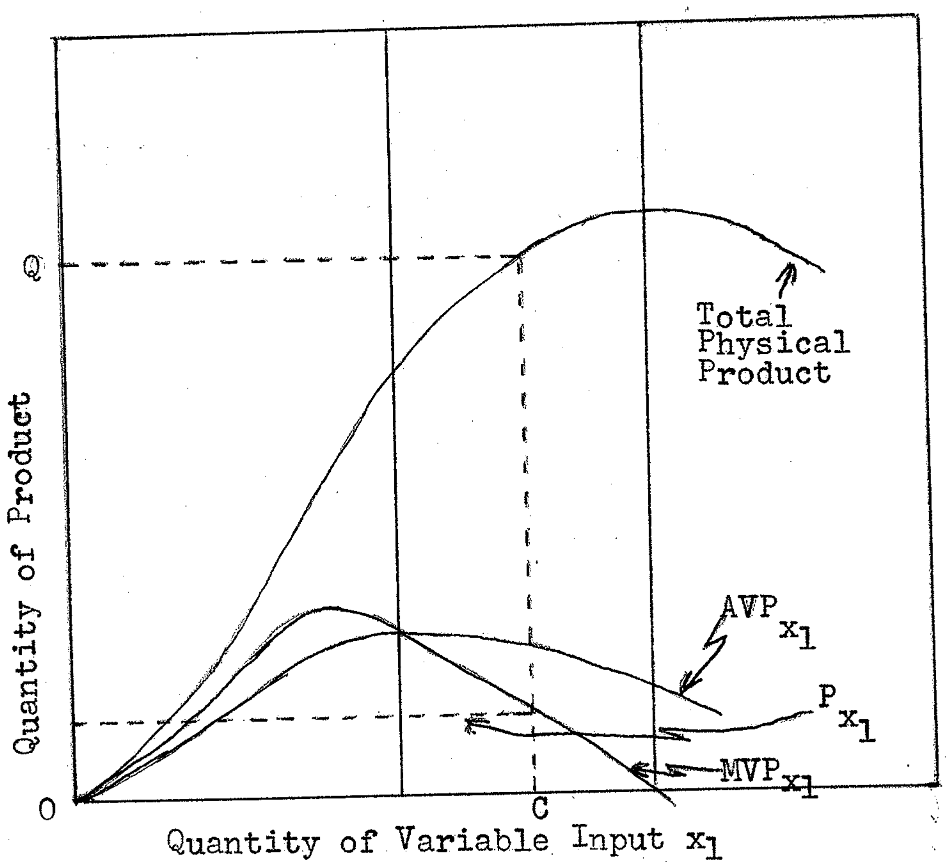

Figure 2. The Marginal Value Product of the Variable Input Equals the Price of the Variable Input

2. For the substitution of one factor for another we shall have donditions of diminishing marginal rate of substitution.

3. For the substitution of one product for another we shall have a condition of increasing marginal costs in terms of the product.

The three price conditions are:

1. The price ratio between any factor and any product must equal the marginal rate of transformation between the factor and the product.

2. The price ratio between any two factors must equal their marginal rate of substitution.

3. The price ratio between any two products must equal the marginal rate of substitution between the two products.

These two sets of conditions may be expressed in three equations:

1. $\frac{MC_j}{MR_i} = \frac{Y_i}{Y_j}$

2. $\frac{MC_{j_1}}{MC_{j_2}} = \frac{X_{j_2}}{X_{j_1}}$

3. $\frac{MR_{i_1}}{MR_{i_2}} = \frac{Y_{i_2}}{Y_{i_1}}$

Where $MC =$ marginal costs

$MR =$ marginal revenue

When the stability conditions given by Hicks prevail then the three equations listed above define the conditions for profit maximization.

These three equations can be illustrated graphically in the Factor-Product, Factor-Factor, and Product-Product diagrams.

Factor-Product relationships:

Figure 3 illustrates the production function:

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

Where $Y =$ product

$X =$ factor

The profit equation is :

$$\pi = Y_1 Py_1 - X_1 Px_1$$

Where $\pi =$ profit

Which states that the product multiplied by its price minus the factor multiplied by its price equals profit.

and

$$Y = \frac{Px_1X_1}{Py_1} + \frac{\pi}{Py_1}$$

Taking the derivative with respect to X_1

$$\frac{dY_1}{dX_1} = \frac{Px_1}{Py_1}$$

Which is the point of tangency of the production function and the price line.

Factor-Factor relation:

The equilibrium price ratio between any two factors must equal their marginal rate of substitution.

This statement is equivalent to saying that the point of least cost production is the point where the slope of the iso-cost line is equal to the slope of the iso-quant.

$$\text{Cost } (C) = Px_1X_1 + Px_2X_2$$

$$X_2 = \frac{C}{Px_2} - \frac{Px_1X_1}{Px_2}$$

Taking the derivative with respect to X_1:

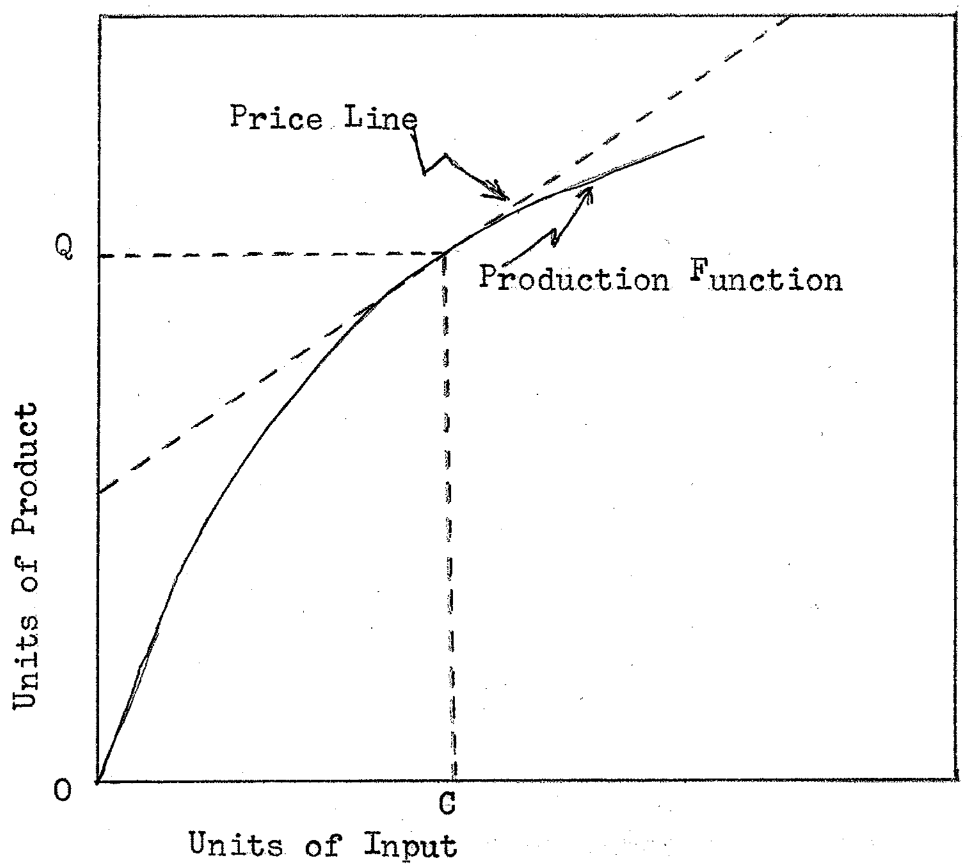

Figure 3. The Tangency of the Production Function and the Price Line in Equilibrium

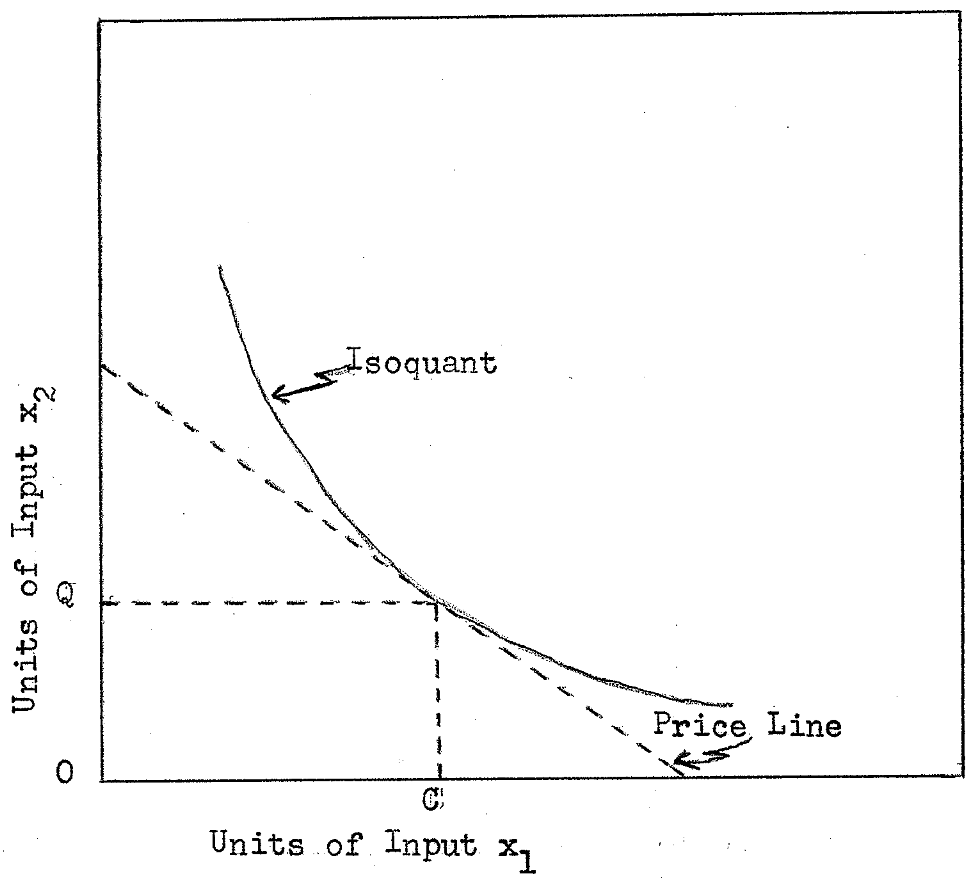

Figure 4. The Equality of Price Ratio and Marginal Rate of Substitution Between Factors of Production in Equilibrium

$$\frac{dX_2}{dX_1} = - \frac{Px_1}{Px_2}$$

i.e. the slope of the iso-quant is equal to the negative slope of the price line. (See Figure 4).

Product-Product relationship:

Two products are competitive if an increase in production of one makes a reduction in the other necessary, given a particular level of the resource.

Two products are complementary when a transfer of resources to one product and an increase in the production of it is accompanied by increased production of the other.

Two products are supplementary if the production of one can be increased without increasing or decreasing production of the other.

The maximum net revenue is obtained when the physical rate of substitution between two products is equal to the rate at which the products exchange in the market, or when:

$$\frac{Y_2}{Y_1} = \frac{Py_1}{Py_2}$$

This means that the slope of the production possibility curve must equal the slope of the iso-revenue curve. (See Figure 5).

Total Revenue : $Y_1Py_1 + Y_2Py_2 = R_{12}$

$$Y_2 = \frac{R_{12}}{Py_2} - \frac{Py_1Y_1}{Py_2}$$

Taking the derivative with respect to Y_1

$$\frac{dY_2}{dY_1} = \frac{-Py_1}{Py_2}$$

I.e., the slope of the production possibilities curve is equal to the slope of the iso-revenue curve at the point of maximum profit.

Returns to Scale:

The conditions which we have been discussing are relevant to situations where only one factor of production is varied while others are held constant. What happens when all factors are varied simultaneously will depend on the elasticity of production of the variables.

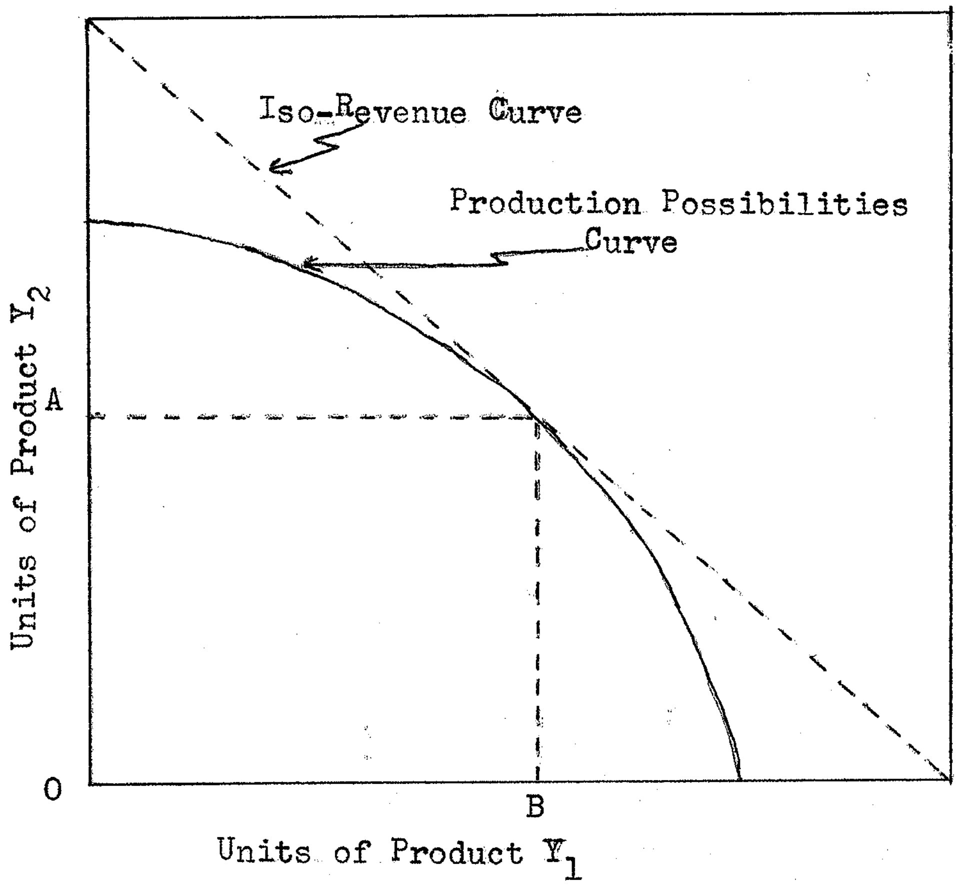

Figure 5. The Slope of the Production Possibilities Curve Equals the Slope of the Iso-revenue Curve at the Point of Maximum Profit

If, when we vary all factors of production by a set amount, total production rises by a greater ratio than the factors of production were increased, then we have increasing returns to scale. If total production rises by a lesser ratio than the factors of production, then we have decreasing returns to scale. If production rises at the same ratio as the factors of production, then we have constant returns to scale.

CHAPTER IV

METHODOLOGY

Production functions are a formal way of expressing the functional relationship between resource inputs and product outputs.

Multiple regression analysis uses the method of least squares to estimate the production curve which best fits the data recorded.

Many of the problems in agricultural production economics research center around selecting and using appropriate equations to describe basic input-output relationships.

We are ordinarily faced with the problem of which of the alternative functions best describes our phenomena. Direct tests are not available for choosing between such widely different functions as the Spillman, Cobb-Douglas, Quadratic, Cross product or Square root equation.

The Cobb-Douglas is the most frequently used. It facilitates estimation of marginal productivity, while allowing for diminishing productivity of each resource.

The quadratic equation appears to be more appropriate in some respects, but computational difficulties make its use prohibitive with conventional computing equipment. Ease in calculating may be more important than preciseness of the estimate where the differences are small.

The Cobb-Douglas production function has the following characteristics:

1. Constant elasticity of production.

2. Diminishing, increasing or constant marginal productivity; it does not permit both increasing and decreasing marginal productivity of a resource in the same equation.

3. The marginal productivity of one resource depends on the level of the other resources.

4. One resource can never be substituted entirely for another resource in producing a given quantity of product.

5. The marginal rate of substitution between resources is constant along the scale line.

The Cobb-Douglas equation has major advantages over other functions.

It enables calculation of physical input-output ratios to be used for farm guidance and to provide benchmarks of how efficiently resources are being used on the farms.

The Cobb-Douglas function does not provide refined guides as to which specific practices or resources a farmer should use but it does provide rough approximations for examining resource efficiency.

The general form of the equation is:

$$Y = aX_1^{b1}X_2^{b2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots X_n^{bn}e$$

In the logarithmic form the equation is:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 \ldots\ldots\ldots b_n \log n + \log e$$

Where Y is the dependent variable representing output and X_1, X_2, ...X_n are independent variables representing inputs of factors of production and b_1, b_2, ...b_n are elasticities of the independent factors of production, and e is the random residual.

The Cobb-Douglas theory of production originally had as its objective the measuring of the relative importance of capital and labor in their contribution to gross income.

If the sum of the b_1, b_2, ...b_n is:

1. Equal to one, returns to scale are constant

2. Greater than one, returns to scale are increasing

3. Less than one, returns to scale are decreasing

The closer the sum of the elasticities is to unity, the more confidence that can be placed in the accuracy of the estimate.

Originally the equation had only two independent variables, Capital and Labor. Notice the following quotations from "A Theory of Production":

"The progressive refinement during the recent years in the measurement of the volume of physical production in manufacturing suggests the possibility of attempting (1) to measure the changes in the amount of labor and capital which have been used to turn out the volume of goods, and (2) to determine what relationship existed between the three factors labor, capital and product."[11]

Cobb and Douglas did, however, look forward to the time when the third factor of production, natural resources, could be included in the equation:

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[11] Charles W. Cobb, and Paul H. Douglas, "A Theory of Production," <u>American Economic Review</u>, 18; 1928. p. 139.

"Finally we should ultimately look forward towards including the third factor of natural resources in our equations and of seeing to what degree this modifies our conclusion and what light it throws upon the laws of rent.

These are tasks which will require much time to complete but we submit that they are necessary if precise relationships which probably lurk within economic phenomena are to be detected and measured."[12]

With these quotations in mind, variables to be included in the equation will be the economic physical factors of production: namely land, labor and capital.

In order to compare any group of factors it is essential that they first be reduced to a common denominator. The easiest way of doing this within the model is to measure each factor at its cost for the period in question. Therefore the production function equation for the model is:

Gross Income = f(Total cost of production)

$$Y = f(X_1, X_2, X_3, X_4, X_5)$$

where

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[12] Ibid., p.165.

Y = Gross income

X = Machine costs

X = Labor costs

X = Land costs

X = Fertilizer costs

X = Remaining costs of production

in the exponential Cobb-Douglas equation:

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}.$$

This function is linear in logarithims:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3$$
$$+ b_4 \log X_4 + b_5 \log X_5.$$

By expressing gross income as a function of total cost of production and by eliminating non-quantifiable factors such as management, the analysis fulfills the basic requisites of objective scientific enquiry; i.e., any number of investigators starting with the same data and following the same procedures are bound to arrive at the same answer.

Definitions of the variables:

Gross income (Y)

Gross income is the value of field crop production, custom work and miscellaneous income, all in dollars.

Machine costs (X_1)

The machinery input is a heterogeneous bundle of machines used in field crop production. Any machine used exclusively in uses other than field crop production was not included. Fixed machine costs were calculated on the basis of undepreciated capital value of the machine complement at the beginning of the period. Total machine costs include all of the costs of owning the machines for the period, including depreciation and interest on investment, repairs, insurance and licences. Depreciation was calculated at the rate of 12% and interest on investment at the rate of 6% on the capital value of the machines at the beginning of the period.

Labor (X_2)

Two measures for labor were recorded in the farm management data:

1. The number of work units[12a]
2. The months of labor available

[12a] Work units- number of 10-hour days of directly productive work usually associated with a crop or livestock program. Work units in crops are calculated on a per acre basis; cereals and small seeds .3, hay and hay silage .6, corn silage 1.2. Work units in livestock are calculated on a per animal unit basis: milk cows 10.0, beef cows 2.0, bulls 4.0, young stock 1.5, sows & boars 10.5, market hogs 1.0, ewes 3.5, lambs 2.8, hens 10.0, turkeys 5.0. Source: Western Manitoba Farm Business Association Report.

"Work unit" is not the amount of labor actually used during the period but is a standard. If labor input were measured in work units, labor would likely be highly correlated with gross income.

"Available labor" includes the maximum number of months of labor which could have been used on the farms from the labor force provided by the members of the family plus hired labor. Since much of the labor was available during the winter months when it could not be used in field crop production, the calculated marginal value product for labor could be lower than expected.

The months of labor available were used as a measure of labor in this study. Because only the value of field crop production was under consideration, only the percentage of available labor utilized in field crop production was entered as a variable. This was calculated on the basis of the percentage of work units that were used in field crop production.

Land (X_3)

To measure the relative contribution to gross income of the land variable, land was measured at its cost for the period.

Land costs include: taxes, interest for the production period on capital investment in land at the beginning of the period, and gross rent.

Fertilizer (X_4)

This variable was taken to be the dollar value of the fertilizer used during the period.

Residual (X_5)

This variable was made up of all the remaining costs of production. This includes : Insurance, other dues, farm papers, box rent, bank charges, small tools, building costs, sprays, fuel oil and grease.

According to Heady:

"Trant found that Cobb-Douglas functions fitted to multiple-enterprise farms yielded unreasonable results. Coefficients for two input categories, land and labor, were negative while other coefficients bore absurd relationships to each other. After the multiple enterprise farms were eliminated from the sample, more reasonable results were obtained."[13]

In an attempt to avoid this difficulty, only farms deriving 60% or more of their income from field

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[13] Earl O. Heady, <u>et. al.</u>, <u>Resource Productivity, Returns To Scale and Farm Size</u>, The Iowa State College Press, Ames, Iowa, U.S.A. p. 107.

crop production were included in the micro data used in this study. Income and expenses from enterprises other than field crops were not included.

CHAPTER V

EMPIRICAL RESULTS

The results of the analysis of the micro data from the two farm business associations indicates that the areas are different in many respects. Farming practices which are ideal in one arèa are not ideal in the other. Each area appears to be an individual.

Machine costs were higher in the Carman area than in the Western area (Tables I and II). This could be due to the different rotations that were followed in the two areas. The Carman area in 1966 had 91.5% of its cultivated acreage in crop. Labor utilization was similar in the two associations (Table III). In the Carman area one month of labor was, on the average, enough to handle 45 cultivated acres, while in the Western area the equivalent area was 49 cultivated acres.

Land costs were higher in the Carman area than in the Western area. Rent, taxes and interest on investment were $9.09 per cultivated acre while in the Western area they amounted to only $6.60 per cultivated acre. Thus, on the average, costs of land in the Carman area were $2.49 more per cultivated acre than they were in the Western area. The land in the Carman area costs about 38% more to possess than does the land in the Western area.

Fertilizer costs in the Carman area amounted to $4.09 per seeded acre. In the Western area fertilizer was applied at the rate of only $3.09 per seeded acre. This may have implications when we consider the different rotations which were followed in the two areas. This implication is not necessarily that the Western area should be applying more fertilizer. There is a probability that one technical coefficient such as fertilizer application will differ as between areas.

Machine costs per month of labor averaged $346 in the Carman area. In the Western area they were $281 (Table III). These values can, under certain circumstances, be taken as the value of labor, because of the possibility of directly substituting labor for machines or vice-versa. For example, if a man had a section of land, for which the only labor used was his own (a one man operation), and for which the machine costs per month of labor was $346, and if he doubled his operation and took on another section of land, he would have the choice of either doubling his labor complement and using the same machine complement, or doubling his machine complement and using the original labor complement. So the value of labor would be $346 per month. This sort of substitution would, of course, be possible only within certain limits. What we are really interested in is the combinations of labor and machinery as identified by their marginal value products. It is only when machine costs are combined with labor costs and their combined output that an estimate of the value of labor can be obtained.

TABLE I

CHARACTERISTICS OF SAMPLE FARMS IN THE CARMAN AREA

(Values in dollars)

Item	Total	Average per farm	Per cultivated acre Average	Range High	Range Low
Machine Costs	226515	5148	7.64	16.77	3.36
Land Costs	275529	6262	9.09	13.27	3.52
Fertilizer Costs[a]	117710	2675	4.09	10.46	.94
Capital Value of Machines	928078	21092	31.00	73.23	11.66
Gross Income	927523	21103	30.06	60.38	11.98
Net Income	122210	2778	4.91	29.04	-12.58

Source: Sample consists of farms for which records were kept by members of The Carman District Farm Business Association for the year 1966.

[a] Fertilizer costs are per seeded acre

TABLE II

CHARACTERISTICS OF SAMPLE FARMS IN THE WESTERN AREA

(Values in dollars)

Item	Total	Average per farm	Per cultivated acre	Range	
			Average	High	Low
Machine Costs	165883	3191	5.92	17.11	1.79
Land Costs	187982	3615	6.60	14.20	2.00
Fertilizer Costs[a]	64213	1234	3.09	8.20	.38
Capital Value of Machines	648757	12476	23.51	78.47	4.24
Gross Income	850391	16963	30.56	55.43	14.41
Net Income	290868	5594	9.64	32.69	-15.26

Source: Sample consists of farms for which records were kept by members of The Western Farm Business Association for the year 1966.

[a] Fertilizer costs are per seeded acre

TABLE III

RELATIONSHIP BETWEEN MACHINE COSTS LABOR AND LAND UTILIZATION

Item	High	Average	Low
Machine Costs per Month of Labor Carman ($)	887	346	132
Machine Costs per Month of Labor Western ($)	533	281	82
Cult. Acres per Month of Labor Carman (Acres)	87	45	14
Cult. Acres per Month of Labor Western (Acres)	88	49	18
Percentage of Cult. Acres Seeded Carman (%)	100	91	73
Percentage of Cult. Acres Seeded Western (%)	100	71	58

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association.

Marginal Productivity Estimates:

The production function analysis by multiple regression resulted in the following Cobb-Douglas equations:

Equation (1) The Carman Area 1966. Number of farms in the sample 44.

$$Y = 1.33656\ X_1^{.327}\ X_2^{.231}\ X_3^{.016}\ X_4^{.268}\ X_5^{.150}$$

In log form:

$$\log Y = 1.33656 + .327 \log X_1 + .231 \log X_2 + .016 \log X_3$$
$$.268 \log X_4 + .150 \log X_5$$

Equation (2) The Western Area 1966. Number of farms in the sample 52.

$$Y = 1.28634\ X_1^{.279}\ X_2^{.139}\ X_3^{.377}\ X_4^{.063}\ X_5^{.082}$$

In log form:

$$\log Y = 1.28634 + .279 \log X_1 + .139 \log X_2 + .377 \log X_3$$
$$+ .063 \log X_4 + .082 \log X_5$$

where

Y = Gross Income

X_1 = Machine Costs

X_2 = Labor

X_3 = Land Costs

X_4 = Fertilizer Costs

X_5 = Residual Costs

The Regression Coefficients, Coefficients of Determination and Tests of Significance:

The regression coefficients, coefficients of determination and tests of significance are presented in Table IV.

In the Carman area the sum of the elasticities was 0.99294 indicating that the returns to scale are slightly less than constant. All of the regression coefficients are significant at the levels shown in the table with the exception of the land variable. The coefficient of determination was 0.65 indicating that 65% of the variations in income could be explained by the factors included in the regression equation.

In the Western area the sum of the elasticities was 0.94216 which would indicate that here also the returns to scale are slightly less than constant. All of the regression coefficients are significant at the levels shown in the table. The coefficient of determination was 0.68 indicating that 68% of the variations in income could be explained by the factors included in the regression equation.

t tests of significance values:

The machinery input in the Carman area is significant at the 10% level. In the Western area at the 1% level.

The labor input in the Carman area is significant at the 20% level, and the Western sector at the 40% level. These relatively narrow significance limits can be expected in an industry such as agriculture which features individual entrepreneurs and perfect competition. The labor input is not homogeneous. Each individual has his own desires and abilities. At Carman an average month of labor handled 45 cultivated acres, varying from a high of 87 to a low of 14. In the

Western area a month of labor on the average handled 49 cultivated acres with a variation from a high of 88 to a low of 18 cultivated acres. The nature of the agricultural sector permits each individual to select his own production goal. Thus narrow confidence limits are to be expected. In a modern factory each worker produces the same as his contemporary in that factory, but here production is geared to the slowest worker so the aggregate production suffers.

The regression coefficient for the land input at Carman is not significant at any level. This might be caused by the unnatural factor of flooding in the year 1966. In the Western area the land factor of production is significant at the 1% level.

The fertilizer factor of production estimate is significant at the 1% level at Carman. In the Western area it is significant at the 40% level. This difference might be due to the fact that farming techniques in this area are not so uniform as in the Carman area. At Carman on the average 91% of the cultivated acreage is in crop, varying from a high of 100% to a low of 73%. In the Western area on the average only 71% of the cultivated acreage is in crop, varying from a high of 100% to a low of 58%. Analysis is hard to conduct on this type of a sample. If an individual had 100% of his land in crop it might be profitable for him to apply fertilizer even up to $11 or $12 per seeded acre. If, however, most of his seeded acreage had been summer-fallowed the previous season, then it would be uneconomic to use such a large application. The estimate would probably have wider significance limits if the sample could be segregated further in this respect, but the sample is not such as to permit this.

Marginal Productivity of Machinery

Machinery investment is a large and important item in the farm business. In the Carman area farms have an average of $21092 invested in machinery or about $31 per cultivated acre. In the Western area farms have an average of $12476 invested in machinery or about $24 per cultivated acre.

TABLE IV

REGRESSION COEFFICIENTS, COEFFICIENTS OF DETERMINATION AND TESTS OF SIGNIFICANCE

Resource Input	Carman 1966 Equation (1) Value of Coef. b_i	t test	Western 1966 Equation (2) Value of Coef. b_i	t test
Machinery Input X_1	0.32684	10%	0.27905	1%
Labor Input X_2	0.23131	20%	0.13956	40%
Land Input X_3	0.01688		0.37791	1%
Fertilizer Input X_4	0.26791	1%	0.06373	40%
Residual Input X_5	0.15000	40%	0.08263	5%
Sum of Coefficients	0.99294		0.94216	
R^2	0.65088		0.68470	

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association.

This is a measure of what is on each farm in the form of undepreciated capital equipment.

If the machine complement were too small then production might suffer from the lack of machinery, while if it were too large then the marginal cost of the machine might be greater than the marginal value of the product. It is important to know if the added investment is paying for itself.

Data in Table V indicates the marginal value productivity of machinery. The marginal value productivity of an additional dollar of machinery cost was $1.37 for 1966 at Carman when machine costs were at the average of $5148. The total return to this factor then would amount to $7052. This would yield a net return of $1904. With an average investment in machinery of $21092 per farm, the return to this factor of production would be about 9% in excess of machine costs. When the costs were reduced to $3500 the marginal value productivity was $1.77 and it declined to $0.97 per dollar of machine costs when the machine costs were increased to $8536.

Data in Table VI indicates the marginal value productivity of machinery in the Western area. When machine costs were held at the average of $3191 the marginal value productivity is $1.48 per dollar of machine costs. The total return, at this level of production, to this factor of production amounts to $4722. This would give a net return of $1531. With the average machine investment of $12476 this would mean a return of about 12.2% to the machine investment in excess of machinery costs. With machine costs of $1500 the marginal value productivity of machinery would be $2.55, while it would decline to $0.86 if the machine costs were to increase to $6748.

Marginal Value Productivity of Labor

Data in Table VII indicates the marginal value productivity of labor in the Carman area. When the average amount of labor of 15.6 months were employed, the marginal value productivity of labor was \$319.89, while it rose to \$391.38 when only 12 months of labor were employed, and dropped to \$286.55 when 18 months were used.

If the price of labor was taken to be \$232[14] per month then the least cost amount of labor to employ would be 23.6 months. Thus the least cost combination of labor and machinery in the Carman area calls for more labor and less machinery.

The marginal value productivity of labor in the Western area is listed in Table VIII. When 11.4 months of labor is used the marginal value productivity of labor is \$207.34 It rises to \$281.25 when only eight months of labor are used and falls to \$173.70 when 14 months of labor are used. Thus the least cost combination calls for more machinery and less labor.

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[14] Male farm help wages without board 1966 as reported in Year Book of Manitoba Agriculture, Manitoba Dept. of Agriculture, Winnipeg, Manitoba. 1966. p. 33

TABLE V

MARGINAL VALUE PRODUCT OF MACHINERY, CARMAN 1966

Total Machine Cost Annual Input (dollars)	Marginal Value Product of Machinery (dollars)
3500	1.77
4000	1.62
4500	1.50
5148[a]	1.37
5500	1.31
6000	1.23
6500	1.17
8536	0.97

[a] average machine cost

TABLE VI

MARGINAL VALUE PRODUCT OF MACHINERY, WESTERN 1966

Total Machine Cost Annual Input (dollars)	Marginal Value Product of Machinery (dollars)
1500	2.55
2000	2.07
2500	1.77
3191[a]	1.48
3500	1.39
4000	1.26
4500	1.15
6748	0.86

[a] average machine cost

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association

TABLE VII

MARGINAL VALUE PRODUCT OF LABOR, CARMAN 1966

Total Labor Input (months)	Marginal Value Product Labor (dollars)
12	391.38
13	368.04
14	347.62
15.6[a]	319.89
16	313.69
17	299.44
18	286.55
23.6	232.00[b]

[a] 15.6 is the average number of months of labor used

[b] $232.00 is the average farm wage paid over the province

TABLE VIII

MARGINAL VALUE PRODUCT OF LABOR, WESTERN 1966

Total Labor Input (months)	Marginal Value Product Labor (dollars)
8	281.25
9	254.16
10	232.00
11.4[a]	207.34
12	198.38
13	185.14
14	173.70

[a] 11.4 is the average number of months of labor used

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association

Marginal Value Productivity of Land

The marginal value productivity of land in the Carman area is shown in data listed in Table IX. The marginal value product is quite low for this factor in this area. It is very close to negative, which would mean that there would be no marginal product available from this factor to retire capital debt. One reason for this could be that the land in this area is quite expensive to possess. Rent, taxes and interest on investment in this area amounted to $9.09 per cultivated acre, while in the Western area these costs amounted to only $6.60. Thus, the land cost 38% more to possess in the Carman area than in the Western area. At Carman the components of land costs were divided with regards to total land costs as follows: Interest on investment 62%, taxes 17%, rent 21%. In the Western area interest on investment was 61%, taxes 19% and rent 20%. The allocation between the three were much the same in each district but all were absolutely higher in dollars per cultivated acre in the Carman area. Land prices have been advancing very rapidly during the past few years. As with any other factor of production, land can pass the value at which it is economical to use it. Land has more factors which can tend to make its price uneconomic than do other factors of production. A farmer may become attached to a certain farm. A farmer may wish to keep his family close to home and so has a strong desire for a certain parcel of land or an adjacent quarter may be needed to round out an economic unit. Market and weather conditions may work together in a certain year to return an unusually high profit. These facts and many more may tend to push the price of land above its economic value. Once land has been traded at these uneconomic prices a market tends to become established. With uneconomic land prices a farmer is better advised to intensify his operations rather than to attempt to extend his operations.

The Marginal Value Productivity of Land is the Western area is shown in the data listed in Table X. When land cost was $3615 the return per dollar of land costs was $1.77. When land costs were reduced to $2000 the marginal value productivity rose to $2.56. When land costs were increased to $5000 marginal value productivity dropped to $1.44.

If a farmer had a section of land with a book value of $40000 and land taxes of $800, his land costs (taxes and interest on investment at 6%) would be $3200. With a return of $1.77 per dollar of land costs, then the total return to land would be $5664 which would be the return of the land costs of $3200 plus a return for the retirement of capital land debt of $2464 or about 6% of the book value of the land. This 6% return is in addition to interest on total investment in land at the assumed relevant rate.

Marginal Value Productivity of Fertilizer

The marginal value productivity of fertilizer for the Carman area is shown in the data listed in Table XI.

With an outlay of $2675 ($4.09 per seeded acre see Tables I & XI) for fertilizer the return per dollar spent for this factor was $2.16. If the amount spent was reduced to $1000 per farm ($1.55 per seeded acre)

TABLE IX

MARGINAL VALUE PRODUCT OF LAND, CARMAN 1966

Total Land Cost Input (dollars)	Marginal Value Product of Land (dollars)
4500	0.080
5000	0.070
5500	0.060
6262[a]	0.055
6500	0.053
7000	0.049
7500	0.046

[a]6262 is the average land cost

TABLE X

MARGINAL VALUE PRODUCT OF LAND, WESTERN 1966

Total Land Cost Input (dollars)	Marginal Value Product of Land (dollars)
2000	2.56
2500	2.23
3000	1.99
3615[a]	1.77
4000	1.66
4500	1.54
5000	1.44
6400	1.24

[a]3615 is the average land cost

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association

then the marginal value productivity would rise to $4.44 while it would drop to $1.61 if the amount applied rose to $4000 per farm ($6.23 per seeded acre). The marginal value product of fertilizer does not fall to its price until the amount applied per seeded acre rises to $11.85 ($7577 per farm).

With an average of 91.5% of the cultivated acres seeded in 1966, the potential for commercial fertilizers seems to be quite high in the Carman area. The production function indicates that more fertilizer could profitably be used here.

The farm with the highest net income in the Carman area ($29.04) had 100% of the cultivated acreage seeded in 1966 and applied fertilizer at the rate of $10.46 per seeded acre. This farm had 285 acres under cultivation and a gross income of $17211 or $60.38 per acre. The labor used was 9 months which gives a net income of $919 per month of labor.

In the Western area returns to fertilizer were somewhat lower; this may reflect the fact that a larger portion of the cultivated acreage is summerfallowed each season. In the Carman area 91.5% of the cultivated acreage was seeded in 1966, while in the Western area only 71.3% of the cultivated acreage was seeded. Summerfallowing is a method of raising the fertility of the soil so it would seem reasonable that the returns to fertilizer should be less in the Western area (the range at which fertilizer may be profitably applied is narrower). This is supported by the higher returns to the land variable in this district previously shown. Presumably the return to a particular cultural practice would be attributed to the resource it is most closely associated with.

When fertilizer was applied in the Western area at the average rate of $1234 per farm ($3.09 per seeded acre see Tables II & XII) the marginal value return to fertilizer was only $0.86 per dollar. When the application was reduced to $500 per farm ($1.26 per seeded acre) the marginal value return rose to $2.02 per dollar of cost. Returns fell to $0.55 when application rates were increased to $2000. per farm ($5.06 per seeded acre). See data listed in Table XII. Marginal value product of fertilizer rose to its cost when application rates were reduced to $1061 per farm or about $2.70 per seeded acre.

These results seem to indicate that the farmers in the Western area may be applying too much fertilizer. When interviewed by the Field Editor of the Country Guide a member of the Western Manitoba Farm Business Association made the following statement:

"Research results showed me that fertilizer on barley really paid off on my farm. Following a university trial last year, soil test result called for 38 lb. of nitrogen fertilizer to grow barley. We put on 70 lb. Thirty-eight pounds might have been enough to grow an average crop, but that's not what we wanted. We know that big yields pay us best and that's what we want to go for."[15]

After obtaining a soil test which called for 38 pounds of fertilizer, it would seem to be uneconomic to apply 70 pounds just to obtain a larger yield. Many farm papers contain references regarding the

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[15] Country Guide, December, 1968, p. 22.

TABLE XI

MARGINAL VALUE PRODUCT OF FERTILIZER, CARMAN 1966

Total Fertilizer Input (dollars)	Marginal Value Product of Fertilizer (dollars)
1000	4.44
1500	3.30
2000	2.67
2675[a]	2.16
3000	1.98
3500	1.77
4000	1.61
7577	1.00

[a]2675 is the average fertilizer cost

TABLE XII

MARGINAL VALUE PRODUCT OF FERTILIZER, WESTERN 1966

Total Fertilizer Input (dollars)	Marginal Value Product of Fertilizer (dollars)
500	2.02
750	1.38
1000	1.05
1234[a]	0.86
1500	0.72
1750	0.62
2000	0.55

[a]1234 is the average fertilizer cost

Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association and The Western Manitoba Farm Business Association

possibility of farmers losing money by not applying enough fertilizer; however there seems to be a paucity of warnings regarding the possibility of losing money by applying too much fertilizer.

Marginal value productivity of fertilizer rises to $1 per dollar of fertilizer costs when application rate is reduced to $1061 per farm or about $2.70 per seeded acre (54 pounds of 11-48-0).

On the basis of this analysis then about $0.43 too much per seeded acre is being spent on fertilizer, or about $168 per farm on the average. This would mean a total of about $8676 for the fifty two farms in the sample.

The farm with the highest net income per cultivated acre in this area ($32.69) had 58% of its cultivated acreage seeded in 1966 and applied fertilizer at the rate of $2.37 per seeded acre. This farm had 672 acres under cultivation and a gross income of $37249 or $55.43 per cultivated acre, with a net income per month of labor of $1315.

While it is recognized that many other factors enter into the determination of net income besides fertilizer application, nevertheless these two examples seem to support the estimates of optimum resource use derived by the Cobb-Douglas production function. Specific recommendations based on the estimates from this function are likely to be fairly reliable.

Further, the distinct differences between the two districts being studied gives a deeper insight into the possibility of factor substitution than would be possible by examining the data from one district alone.

All farm technology is moving in a certain direction. Because of its location, techniques employed, and the nature of the operation, agriculture at Carman seems to have moved further than in the Western area. With this evolution the latitude for factor substitution is not so great in many respects. With high land costs it becomes necessary to utilize the land factor to the fullest extent. Thus it is necessary to increase the employment of the other factors of production: fertilizer, machinery and labor.

In the Western area the knit is not so close. Because of cheaper land costs it is possible to substitute cultural practices for some of the other factors of production.

If more of the land is summerfallowed each season, not so much labor is required because the work load is more evenly distributed over the whole season. This is also true of machine use. When 100% of the cultivated acreage is seeded there are peak periods when it is necessary to have excessive amounts of machinery in order to meet deadlines . The cultural practice of summerfallowing is also recognized as a device for raising soil fertility and so it also substitutes for fertilizer. This relationship between the cost of land and the cost of other factors of production is important in the agricultural sector. The supply of land being relatively inelastic, can cushion the effect of high prices of other factors of production only within certain limits, then its price also rises in unison with the other factors of production.

Marginal Rate of Substitution of Labor for Machinery

The principle of factor combination and substitution permits further insight into the process of resource allocation. Factors of production which are substitutes for each other can be employed in many combinations to produce a given level of output.

Mechanization or the use of machines to replace labor has been taking place for many years. Mechanization has reduced the amount of labor required in farm production but at the same time capital investment in machinery and equipment has added to the farm production costs.

In the process of maximizing production while at the same time minimizing cost, the proper balance between labor and machinery is very important.

We want to find the least cost combination of labor and machinery. In order to find this optimum point it is necessary to find the iso-product curve and the marginal rate of substitution between labor and machinery.

The iso-product equation is as follows:

$$\log X_1 = \frac{1}{bx_1} \log Y - bx_2 \log X_2 - (\log a + bx_3 \log X_3 + bx_4 \log X_4 + bx_5 \log X_5)$$

The equation for the marginal rate of substitution is:

$$\frac{dX_1}{dX_2} = \frac{bx_2}{bx_1} \cdot \frac{X_1}{X_2}$$

The varying combinations of labor and machinery that may be used to produce the average farm income of \$21103 in the Carman area in 1966 are shown in the data listed in Table XIII. This is illustrated in Figure 6.

When 15.6 months of labor were used the machine costs were $4789. When the input of labor was reduced to 12 months the machine costs rose to $5763. When labor was increased to 18 months machine costs fell to $4329.

Data in Table XIV indicate the combinations of labor and machinery that could produce the average income of $16963 in the Western area in the year 1966 (see Figure 15). When 11.4 months of labor were used machine costs were $3160. With only 8 months of labor, machine costs increased to $3771, while with the employment of 14 months of labor machine costs decresed to $2853.

The least-cost combination of labor and machinery is found where the cost of the added machinery just balances the cost of the labor replaced. The least-cost combination is determined where the following equality holds:

$$\frac{\partial X_2}{\partial X_1} = \frac{Px_1}{Px_2}$$

where

TABLE XIII

COMBINATIONS OF LABOR AND MACHINERY TO PRODUCE GROSS INCOME OF $21,103, CARMAN 1966

Col. #	1	2	3	4
	7	8536	.001160	.17
	12	5763	.002947	.44
	13	5447	.003378	.50
	14	5170	.003833	.57
	15	4923	.004313	.64
	15.6[a]	4789	.004611	.69
	16	4704	.004814	.72
	17	4507	.005339	.80
	18	4329	.005886	.88

Col. #1 Months of labor
Col. #2 Machinery cost (dollars)
Col. #3 Indicates the months of labor replaced by one more additional dollar of machine cost
Col. #4 Indicates the hours of labor replaced by one more additional dollar of machine cost

[a] 15.6 is the average number of months of labor used

TABLE XIV

COMBINATIONS OF LABOR AND MACHINERY TO PRODUCE GROSS INCOME OF $16,963, WESTERN 1966

Col. #	1	2	3	4
	2.5	6748	.00074	.11
	8	3771	.00425	.63
	9	3556	.00508	.76
	10	3373	.00595	.89
	11.4[a]	3160	.00723	1.08
	12	3081	.00781	1.17
	13	2960	.00881	1.32
	14	2853	.01056	1.58

Col. #1 Months of labor
Col. #2 Machinery cost (dollars)
Col. #3 Indicates the months of labor replaced by one more additional dollar of machine cost
Col. #4 Indicates the hours of labor replaced by one more additional dollar of machine cost

[a] 11.4 is the average number of months of labor used

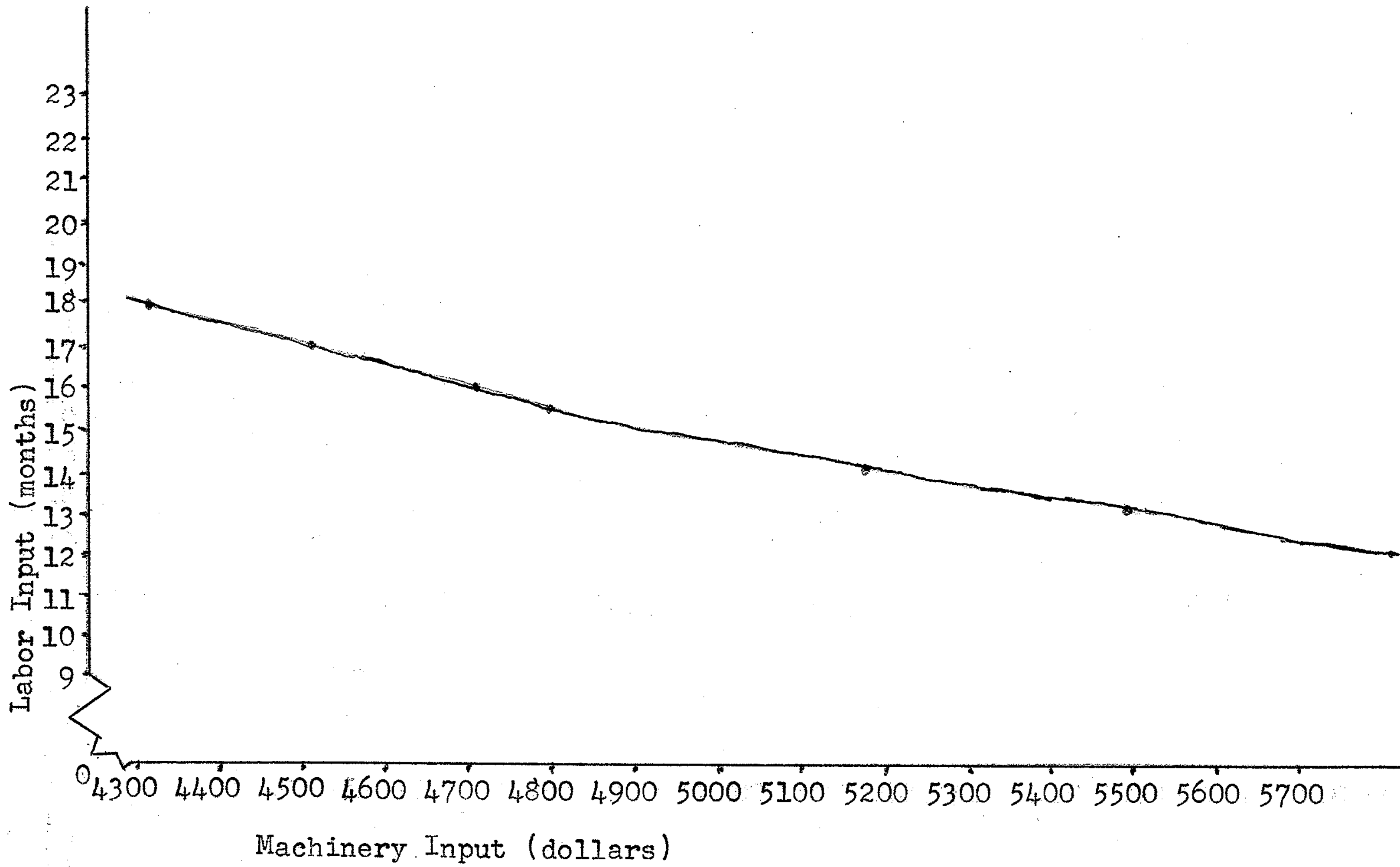

Figure 6 . Marginal Rate of Substitution Labor and Machinery
Carman 1966

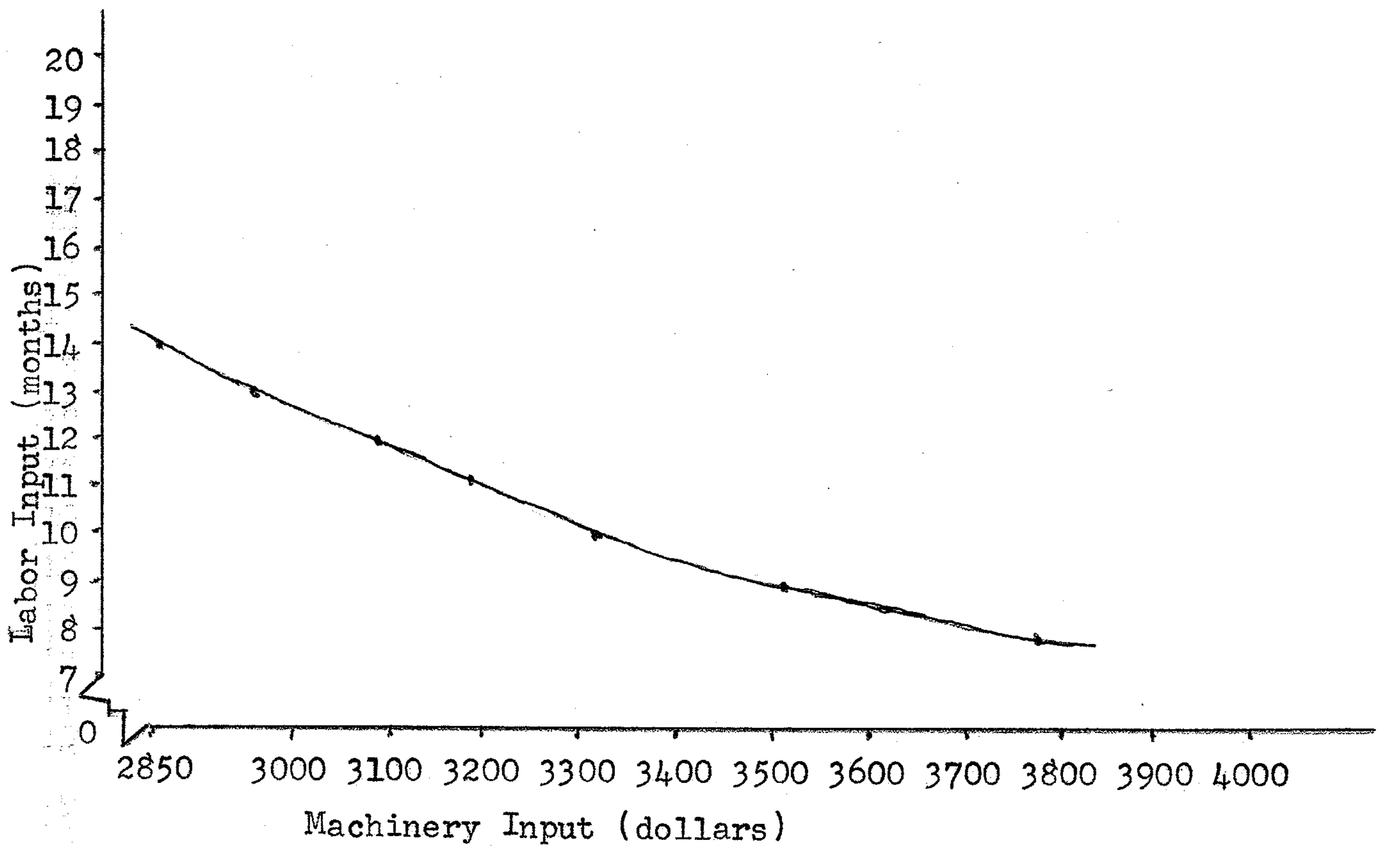

Figure 7 . Marginal Rate of Substitution Labor and Machinery in the Western Area, 1966

$\frac{\partial X_2}{\partial X_1}$ is the marginal rate of substitution of machinery for labor, and Px_1 is the price of machinery input and Px_2 is the price of the labor input.

If we take the price of machinery to be $1 and the price of labor to be $1.29 per hour[16] then the right side of the above equation becomes $\frac{1}{1.29}$ or about .77. In Table XIII we note that the value for $\frac{\partial X_2}{\partial X_1}$ which is closest to this value is .80 where the combination of machines and labor is 17 months of labor and $4507 of machine costs. More labor and less machinery should be used in the Carman area. In the Western area (Table XIV) the marginal rate of substitution which is closest to .77 is .76 where the combination of labor and machinery is 9 months of labor and $3556 of machine costs.

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16 Male farm help wages without board 1966 as reported in Year Book of Manitoba Agriculture, Manitoba Dept. of Agriculture, Winnipeg, Manitoba. 1966 p.33.

Even when the least cost combination of labor and machinery shows that the entrepreneur might maximize profit by employing more labor and less machinery there are many other factors which might influence the individual.

The individual farmer may decide an excessive amount of machinery is more dependable than the human element of labor. The over-sized tractor may be less likely to quit during the busy season. Other entrepreneurs may prefer an excessive amount of machinery to having a hired man because a stranger in the farm home may be regarded as an invasion of their privacy.

Experienced farm help qualified to operate expensive machinery is extremely hard to obtain. Even if it means using some of the marginal product earned by land or labor to subsidize the purchase of excessive amounts of machinery, some farmers may prefer to do so since it enables the entrepreneur himself to personally operate machines which are easily broken and expensive to repair.

On the other side of the coin, when the analysis reveals a least cost combination which calls for the employment of more machinery and less labor in order that profit may be maximized, the individual farmer may prefer having a hired man to having a correct sized machinery complement. Many jobs on the farm are jobs which may be more efficiently carried out when there is more than one man employed. Also to be considered is the fact that unless the hired help is extremely low in mental capacity, they do take a part in the decision making process, and often it can be said that two heads are better than one. Neither will a correctly sized tractor come looking for the farmer if he becomes entangled in the machinery and fails to come home.

The least cost combination in the Carman district economically calls for the employment of more labor and less machinery. The optimum allocation is for the employment of 17 months of labor and $4507 of machinery costs or an average of \$6.42 for each of the 702 cultivated acres in the Carman sample. This compares with the actual average allocation of 15.6 months of albor and \$5148 of machinery costs (Tables V & VII) with the average machine cost per cultivated acre of \$7.64. It would superficially appear that the farmers were over-capitalized with respect to machinery investment. However this is not necessarily so. According to the Department of Engineering, at the University of Manitoba the amount of machinery which is technically required to handle an acre of cultivated ground would have the annual cost of \$12.16 (See Appendix I).[17a]

Conclusions Based on Evidence Presented:

1. The value of labor is a function of the supply of labor and the productivity of the machine. It is also a function of the cost of the machine.

2. The least cost combination of labor and machinery at Carman calls for the employment of more labor and less machinery.

3. Both associations are undercapitalized with respect to machinery investment from the technical point of view on the basis of 1967 prices.

[17a] This is based on 1967 prices for machinery whereas the values from the farm records are distributed over a period of years ending in 1966.

4. Scarcity of labor in the agricultural sector may reduce the flexibility in this sector with regard to the product produced.

5. The marginal value product of labor at Carman and the Western area are \$319.89 and \$207.34 respectively. This compares with the actual average wage paid in the province of \$232 per month.

6. Land is overcapitalized in the Carman area. Under these conditions farmers are better advised to intensify their operations rather than to attempt to extend operations.

7. When land costs are in line with productivity, extensive farming practices are more practical. By using the cultural practice of summerfallow it is possible to substitute land for the other factors of production: machinery, labor and fertilizer.

8. More fertilizer could be profitably applied in the Carman area, while in the Western area the opposite condition holds.

CHAPTER VI

SUMMARY AND CONCLUSION

The object of this study has been to estimate the marginal productivity of resources used in farming in two areas of Manitoba for the year 1966. The productivity estimates were derived by the use of multiple regression analysis and the Cobb-Douglas type of production function. This type of analysis may be used to establish bench marks for over-all resource allocation and under certain conditions may also be used for specific recommendations.

Heady notes that the Cobb-Douglas type of analysis provides 'diagnostic benchmarks' for efficient use of resources, although refinement in procedures may also allow it to be used for specific recommendations.[17]

The productivity estimates derived by the use of the Cobb-Douglas type of production function sheds some light on the allocation of resources in the area under study. The two areas employ different farming techniques and an analysis of this type permits a

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[17] E.O.Heady, et. al., Resource Productivity, Returns to Scale, and Farm Size, The Iowa State College Press, Ames, Iowa. p. 3.

comparison of the two areas to be made.

In considering the hypotheses:

1. There is an optimum balance between the two factors of production: machinery and labor.

Analysis of the data used in this study would indicate rejection of hypothesis number one.

In the Carman area the least cost combination of labor and machinery would maximize profit by using more labor and less machinery. The average amount of labor used in this area was 15.6 months combined with an average $5148 of machine costs. The least cost combination calls for the employment of 17 months of labor and $4507 of machine costs.

In the Western area the average amount of labor used is 11.4 months with an average machine cost of $3191. The least cost combination calls for the employment of 9 months of labor and $3556 of machine costs.

While there is an imbalance in the least cost combination of labor and machinery in both associations, this imbalance is relatively small. Any massive alteration in the employment of these factors of production, such as the removal of 50% of the labor force from the agricultural sector, without a compensating alteration of the machinery cost factor of production is not likely to benefit agriculture on the basis of the sample examined. There are no innovations in sight that would vastly increase the productivity of machinery relative to labor such as the reaper versus the cradle, the oil tractor versus horses, and the combine versus the thresher. This makes the farmer less willing and less able to pay monopolistic prices demanded by the machine companies. The farm sector features perfect competition. The only way the farmer is able to counter excessive machine cost is to increase his productivity. This avenue of escape is not valid if the new machine is no more productive than the one it replaces. The farmer is not able to pass on increased costs by increasing the price of his product.

A large machine company with its chain of dealers and repair depots is much like a hydro or gas line. The farmer is not willing to buy a machine from a company which is not likely to be able to provide repair parts quickly or that does not have an adequate repair depot with qualified mechanics. Once the machine company becomes established with its chain of dealers and repair depots they are able to charge almost any price they desire. It is quite difficult for a new machine company to become established. When a farmer buys a new machine he weighs the price against the availability of a good stock of repairs and qualified mechanics. Even if a new company did finally become established, if it were not subject to some type of control or regulation, it would follow the same route.

In the long run, the over-riding factor is the economics of the situation. That is , if the new machine is more costly in relation to labor and other factors of production than the old machine it replaces, then the optimum balance between labor and machines, instead of requiring more machines and less labor, will require less machines and more labor. No matter how big and beautiful a machine is, if it cannot justify itself economically, it will not be adopted.

Labor is still a very important item on the farm. The fact that the farm with the highest net income per cultivated acre in the Carman area was a farm with only 285 acres under cultivation, and which had a net income per month of labor of $919 attests to this fact. Farming is an art as well as a science and while the science side may function very well operated by machines, the art side still requires the human touch.

Because farms in the Carman area have advanced further than in the Western area, the data from this district is more valuable since it may be used to predict what is likely to happen in the future in the Western region.

2. The optimum balance in the allocation is affected by the area location, the farming techniques, and the other factors of production.

Results obtained would indicate acceptance of hypothesis number two.

The two farm business associations when they are examined in unison provide a unique picture of the relative importance of each of the factors of production and their interdependence. One factor alone could not be varied without affecting the other factors of production and possibly also the product. The balance of the factors of production is highly sensitive to each factor of production in an industry such as farming. It is difficult to say which is the dominant or governing factor.

In the Carman area land is more costly. This could be due to:

1. Closeness to a major population center
2. Density and nature of the farming population
3. Topography suited to farming
4. Long frost free period
5. Inherent productivity of the land
6. Farming techniques employed

It is difficult to determine whether the high cost of land is the cause or the effect of more intensive farming techniques, but it seems to be associated with them.

In order to maximize profits when land prices are high relative to land productivity, it becomes necessary to adopt intensive farming techniques. To return a net profit land must be continuously cropped. Factors such as labor and fertilizer become more important.

In the Western area, where land prices are more in line with productivity, it becomes possible to substitute land, through the use of cultural practices, for the other factors of production. When more of the arable land is summerfallowed each year, the work load is spread more evenly over the entire season. This reduces the total amounts of labor and machinery which are required to meet production deadlines. Summerfallowing has long been recognized as a substitute for fertilizer. It gives the land a rest and builds up the store of soil nutrients. This reasoning is supported by empirical data from the two associations. In the Carman area where 91% of the cultivated acreage was in crop, machine, labor and fertilizer requirements were higher per acre than in the Western area where only 71% of the cultivated acreage was in crop.

When land prices are moderate, extensive farming techniques are required for profit maximization. Land prices are thus quite important in the over all picture, even though land is not the prime object of this study. Land can cushion, and has cushioned the effect of arbitrarily set farm machinery prices. However, the supply of land is relatively inelastic, so the high cost of the other factors of production affects the price of land. Advancing land prices then tend to limit this adjustment.

3. Returns to the land factor of production which provides for the return of land costs and retirement of capital land debt, vary between area location.

Analysis of the data would indicate acceptance of hypothesis number three.

The marginal value product of land in the Carman area was very close to negative. No marginal product was available for the retirement of capital debt.

In the Western area the value of the marginal product of land available for the retirement of capital land debt was about 6% of the capital investment in the land factor of production.

4. Optimum application of fertilizer varies between area location, and with farming techniques employed.

Results of the study would support hypothesis number four.

In the Carman area where 91.5% of the cultivated acreage was seeded in 1966, the returns to fertilizer applied were quite high. When continuous cropping techniques are employed the soil nutrients do not have any opportunity to build up. There is a continuous depletion every year. If fertilizer were not liberally applied this type of farming would not likely be very profitable. The marginal value product of fertilizer here was $2.16 with the application of $4.09 of fertilizer per seeded acre. The marginal value product did not decline to its price until application rates were increased to $11.85 per seeded acre.

In the Wester area with 71.3% of the cultivated acreage seeded, the application of fertilizer had a narrower range. With the average application of $3.09 per seeded acre the returns were only $0.86 per dollar of fertilizer applied. Returns rose to the cost when application was reduced to $2.70 per seeded acre.

BIBLIOGRAPHY

A. BOOKS

Bishop, C.E., and W.D.Toussant. Introduction to Agricultural Economic Analysis. New York: John Wiley and Sons, Inc., 1958.

Davidson, J.Brownlee. Agricultural Machinery. New York: John Wiley and Sons, Inc., 1931.

Hicks, J.R. Value and Capital. Second edition London: Oxford University Press, 1957.

Heady, E.O. et.al. Resource Productivity, Returns to Scale and Farm Size. Ames: The Iowa State College Press, 1956.

Lee, N.E. Harvests and Harvesting Through the Ages. Cambridge: The University Press, 1960.

B. JOURNAL ARTICLES

Cobb, C.W., and P.H.Douglas. "A Theory of Production." American Economic Review, 18; 1928.

C. PUBLICATIONS OF THE GOVERNMENT, LEARNED SOCIETIES AND OTHER ORGANIZATIONS

Manager's Report. Winnipeg: Canada Manpower Center, September, 1967.

Menzies, M.W. *Poverty in Canada*. Winnipeg: Manitoba Pool Elevators, 1965.

MacEachern, G.A. *Address to The Annual Staff Conference, of the New Brunswick Department of Agriculture and Rural Development. January 6, 1969*. Fredericton, New Brunswick.

Yearbook of Manitoba Agriculture. Winnipeg: Manitoba Department of Agriculture, 1966.

D. NEWSPAPERS

Country Guide, December 1968.

APPENDIX I

CURRENT VALUE OF MACHINE COMPLEMENT FOR HYPOTHETICAL FARM OF 850 CULTIVATED ACRES

Item	Description	Value
Tractor	90-100 H.P. 1206 with cab.	$10995
Combine	40" cylinder 403 S.P. P.U.&Cut.	$11136
Swather	16½' S.P.	$ 2935
Drill Press	18' with fert. attach.	$ 3755
Cultivator	Heavy Duty 20'	$ 2147
Disc	wide level 24'	$ 5200
Cultivator	vibra shank 28½'	$ 2606
Harrows	50'	$ 320
Sprayer	40'	$ 409
Truck	with box and hoist Model 1600	$ 5765
Grain Auger	41' 6" 10 H.P.	$ 545
Car	$3500 (one third business portion)	$ 1166
Total Capital Value........................		$46979
Machine Cost per Cult. Acre.[a]..............		$12.16
Machine Investment per Cult. Acre...........		$55.26

Source: Machinery suggested by the Aricultural Engineering Department, University of Manitoba (Two man operation)

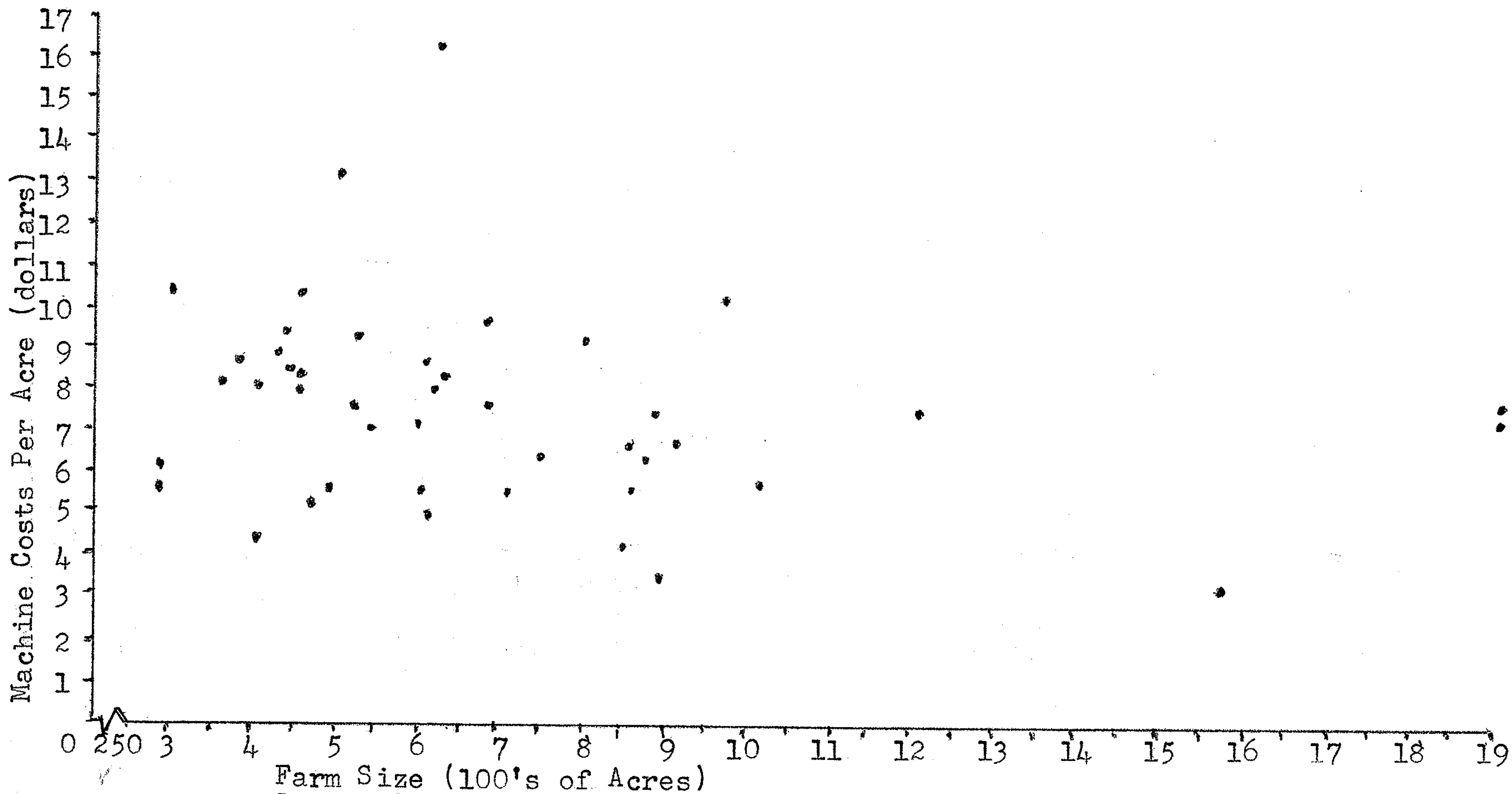
[a] Machine costs were calculated as : Depreciation at 12% of capital value. Interest on investment at 6% of capital value. Repairs taken at 4% of capital value as in <u>Estimating Farm Tractor Operating Costs Using the Budgeting Method</u>, Purdue University Agricultural Experiment Station, Lafyette, Indiana. EC 136 Nov. 1956 p.16

Machines are all International Harvestor.

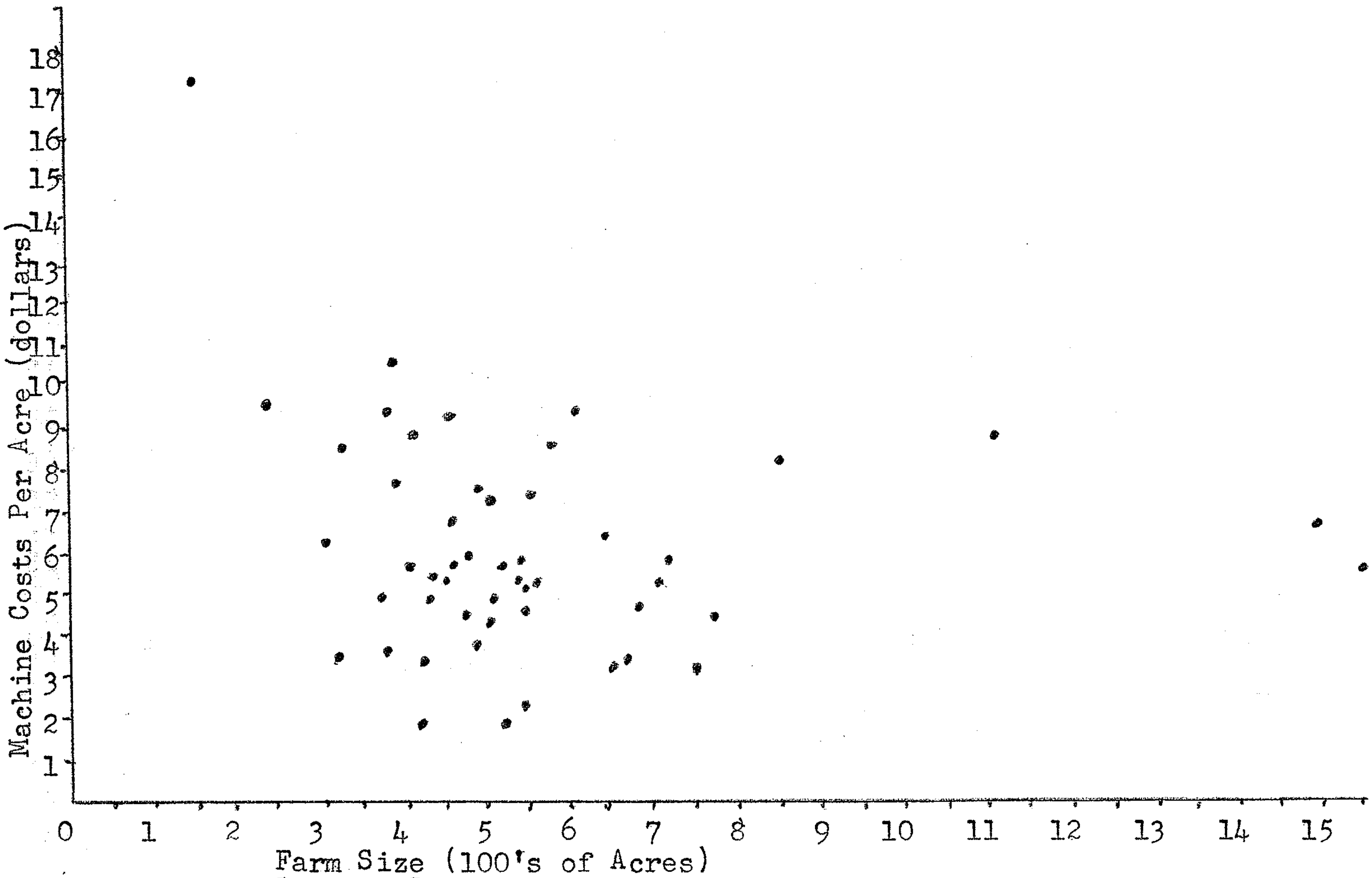
Prices are all F.O.B. Winnipeg. 1967.

APPENDIX II

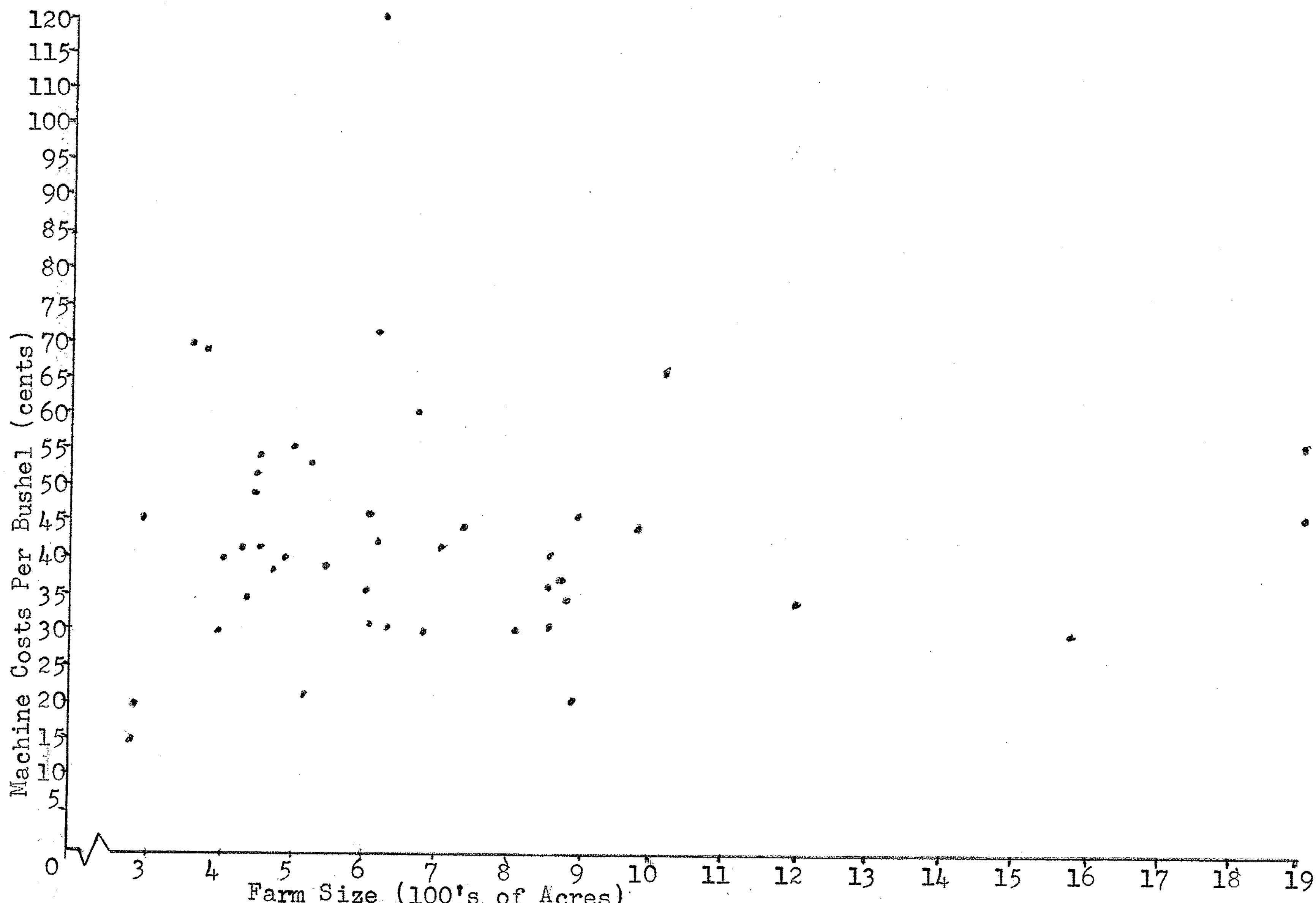
SCATTER DIAGRAMS SHOWING THE RELATIONSHIP BETWEEN MACHINE COSTS AND MACHINE PRODUCTIVITY AND THE RELATIONSHIP BETWEEN MACHINE COSTS AND FARM PRODUCTIVITY.



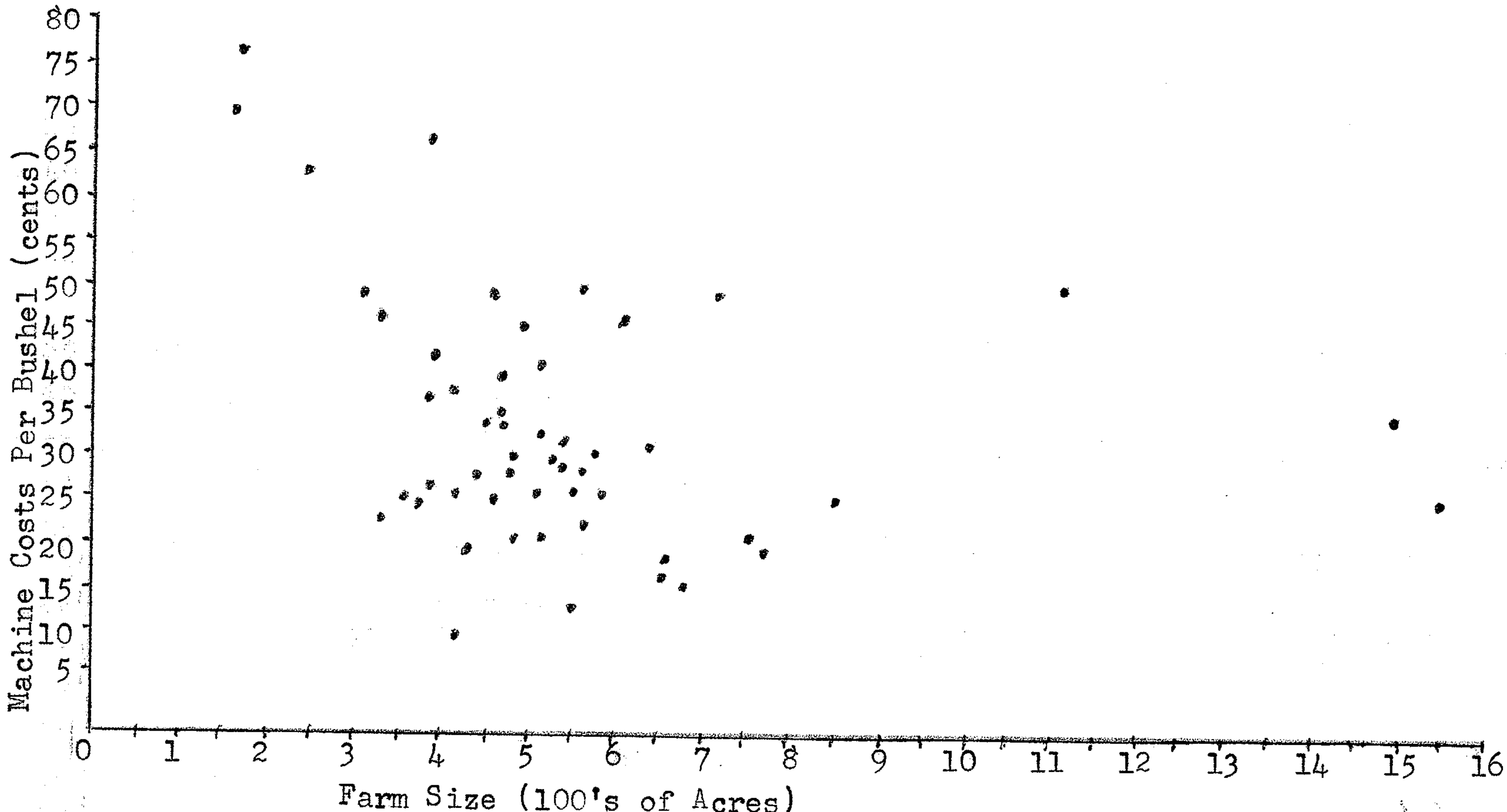
Source Sample consists of farms for which records were kept
by The Carman District Farm Business Association



Source: Sample consists of farms for which records were kept by The Western Manitoba Farm Business Association



Source: Sample consists of farms for which records were kept by members of The Carman Farm Business Association



Source: Sample consists of farms for which records were kept by members of The Western Manitoba Farm Business Association