Economic consequences of varying machinery combinations on dryland spring wheat farms
by Paul Andrilenas

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Economics at Montana State College
Montana State University

Abstract:
The problem of this research is found in the area of minimizing the power and machine cost of accomplishing given tasks on dryland crop farms in the spring wheat area of Montana. Solution of the problem requires estimates of (1) rates at which the tasks are accomplished, as well as costs of the machines, and their use in various combinations and (2) the effect of alternatives in such combinations,on the operation of the farm as a whole.

Machinery combinations selected for the analysis are the types and sizes of equipment most widely used for the planting, fallow, and harvesting operations. The performance rates of 4-plow and 5-plow machinery combinations are related to small (550 acres), medium (.944 acres), and large (2,344 acres) farms to determine the ability of the machinery combinations to meet the timeliness of. operation limits. The alternatives tested are: (1) 4-plow and 5-plow gasoline tractors with given machinery combinations, (2) 4-plow and 5-plow diesel tractors with given combinations, arid (3) ownership of (a) 12-foot, (b) 14-foot, arid (c) 16-fpot self-propelled combines or custom hiring in the harvesting operation.

The second and1 third summerfallow operations were found most demanding of power and machinery for timely operations. The optimum power and machinery were found to be: (1) for the small farm, the 4-plow gasoline combination; (2) for the medium farm, the 5-plow gasoline combination; and (3) for the large farm, two 5-plow gasoline combinations. However, total costs per acre differed little between these optima and the next alternatives. It was found to be cheaper to hire the harvesting done, for 285 acres or less per year, at a custom rate of $3.25. For larger acreages, ownership and use of a 14-foot self-propelled combine would give a lower total harvest cost per acre.

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Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Master of Science in Agricultural Economics

at

Montana State College

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Bozeman, Montana
July, 1956

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ILLUSTRATIONS

ACKNOWLEDGMENTS

The author wishes to express a special debt of gratitude to Professor C. B. Baker for his encouragement and guidance throughout the course of this study. Special thanks are also extended to R. L. Anderson and O. W. Monson, other members of the author's thesis committee, who offered valuable suggestions and criticisms.

Thanks are also extended to the farmers and implement dealers contacted in the course of this study for their time and the information they provided.

Finally, appreciation should be expressed to the staff members of the Department of Agricultural Economics and fellow graduate students for timely advice and encouragement during the writing of this thesis.

ABSTRACT

The problem of this research is found in the area of minimizing the power and machine cost of accomplishing given tasks on dryland crop farms in the spring wheat area of Montana. Solution of the problem requires estimates of (1) rates at which the tasks are accomplished, as well as costs of the machines and their use in various combinations and (2) the effect of alternatives in such combinations on the operation of the farm as a whole.

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PART I

THE PROBLEM

Economic Problem of Farmer:

The rapid shift from animal to mechanical power between 1919 and the present date constitutes one of the most important changes in the history of American agriculture. Improvements in the design and construction of both tractors and auxiliary equipment enabled farmers, relatively unskilled at mechanical work, to operate power equipment. The increased use of farm equipment by farmers enabled them to do all jobs faster and many jobs better.[1/]

This ability to accomplish the farming operations in a more expeditious manner is made to order for the dryland wheat areas with which this problem deals. In dryland areas where net production per acre is comparatively low, farm operators are forced to choose between a lower standard of living or an increase in acreage. As the cultivated acreage increases it becomes necessary for farmers to use power equipment and machinery to cover the required acres. In the case of dryland operations, power equipment and machinery are also substituted for scarce and expensive labor.

The increased use of machinery in the farming operation presents a problem to dryland farmers. As the amount of machinery and power equipment increases, the percentage of investment tied up in farm machinery and the cash costs, relative to total costs incurred by the farm operator, increased. This particular factor is instrumental as the basis for the problem related to economic choices in power equipment and machine use.

1/ F. C. Fenton and G. E. Fairbanks, The Cost of Using Farm Machinery, Kansas State College Engineering Station, Bulletin No. 74 (1954), p. 7.

Although labor costs decrease, fixed costs and variable costs associated with machine investment and use increase. Cash transactions have become a larger part of the farm business due to the necessity of purchasing equipment, fuel, oil, and items of repair to carry on the farming operation.

Farmers are faced with the problem of obtaining an optimum combination of power equipment and machinery relative to the acreage of the farm. This entails minimizing costs subject to timeliness requirements of operation. The farm operator is concerned with obtaining a machinery combination which will (1) minimize costs of given jobs and (2) maximize the returns from his farming operation as a whole.

Input-Output Relationships:

Before going into the various choices available to the farmer with which he can meet the various necessary criteria commensurate with an optimum machinery combination, let us go into some of the basic economic relations involved in maximizing of returns and minimizing of costs.

As a beginning, let us assume the farmer is motivated to so use his resources as to maximize net income. I.e., the present study is concerned with resource use which is "economically rational." Assuming that a farm operator uses certain given techniques in applying a variable factor X_1 with a specific amount of fixed factor X_2. As each increment of the variable input X_1 is added, the amount of product Y_1 (TPP) increases first at an increasing rate, and, as further additions of the variable input are added, at a decreasing rate, leading finally to a maximum in TPP.[2/]

From this total physical product relationship two other relationships can be derived. They are the average physical product (APP_{X1}) and the marginal physical product (MPP_{X1}). The average physical product is obtained by dividing the TPP by the number of inputs of the variable input X_1 needed to produce this level of TPP. Since the TPP curve represents first increasing and then decreasing returns the APP curve will rise and then decline. The marginal physical product curve indicates the rate of change (with respect to X_1) of the TPP curve or the increment to the total physical product with the addition of each unit of input ($\Delta Y/\Delta X_1$). As a result, it can be noted that when TPP curve is at a maximum the MPP is at zero. Previously MPP is a maximum when TPP commences to increase at a decreasing rate.

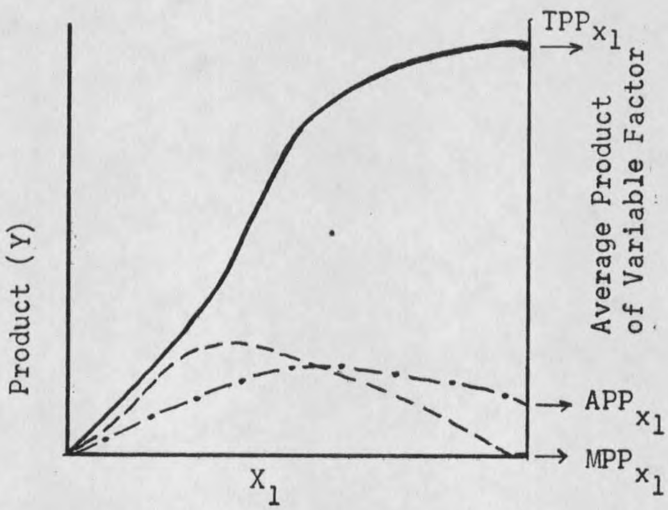

Figure 1. Input Variable Factor

2/ George F. Stigler, The Theory of Competitve Price, (New York, 1942), p. 42-51.

Using these physical input-output relationships we can now proceed toward attaining the primary goal of farm management which is the maximization of net farm income. If the product is sold in a market which gives a price which is a constant with respect to quantity sold, such a maximum will be achieved if two basic conditions are met: (1) that the level of production be extended to the point where the marginal cost of output is equal to the MVP of the output; and (2) that given levels of production be attained at a minimum cost.

To determine at what level of production the marginal cost of output is equal to the price of the output, value relationships must be used. The physical production function can be converted to value terms when it is multiplied by the price of the product. When this is accomplished, total physical product becomes total value of product, average physical product becomes average value of product, and marginal physical product becomes marginal value of product.

The farmer is assumed also to purchase variable inputs in a competitive market which makes the cost of each unit of input identical regardless of the number of inputs used. This makes the addition to total cost (marginal cost of input) equal to the price of the input.

To maximize the income net of the cost of X_1 in this enterprise, the farm operator will increase his use of the factor of production until the marginal value of its product equals its price. Inputs will be added until increments to total cost by the addition of an additional unit of input will equal the increments to total revenue by this same unit of input. Therefore

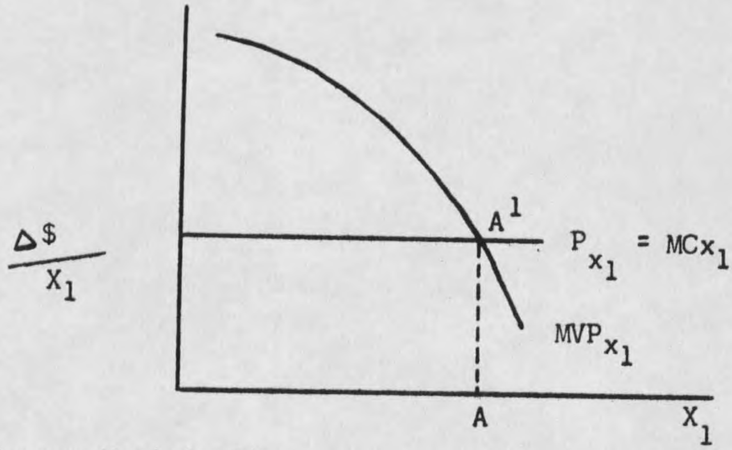

Figure 2. Income Maximization.

the point where income will be maximized will be at the point where $PX_1 = MCX_1 = MVPX_1$, as indicated in Figure 2 at A'.

Although this illustration deals only with one variable factor of production, the same criterion can be used to determine other economic optima. That is, output is increased until the marginal cost of the productive factors is equal to the marginal value of their respective products.

Timeliness of Operation:

Certain time limits are imposed on the different farming operations by climatic conditions. Such factors as length of growing season, time and amount of precipitation during growing season, and temperature variations during growing season determine optimum time periods for particular farming operations. Furthermore, the use of particular varieties of farm crops coupled with the afore-mentioned climatic factors provide additional limits on the timeliness requirements of operation.

In tests conducted at the Northwestern Montana Agricultural Branch Station over a three-year period, oat yields were reduced 33 bushels per acre when planted May 15, instead of May 5. Further tests revealed that barley yields were reduced 10-15 bushels per acre for every five days' delay in planting after May 5 and yields in Pilot Wheat were reduced by four bushels per acre when planting was delayed from May 5 to May 15.3/

These tests indicate that timeliness of operation can be an important factor in the final yields obtained and that the farmer requires equipment with adequate capacity to prevent excessive losses through reduced yields. The adage, "A machine in time may save nine," explains why some farmers own the amount of expensive equipment that they do. Farm operators who have their farms fully equipped with adequate machinery in good condition, have a great advantage in doing jobs during the most productive time interval.

To increase yields through timeliness of operation is just part of the problem involved in this particular aspect of maximizing net farm income. The farmer has another facet to the problem: What are the added costs involved in increasing yield? Eventually, additional equipment costs involved in attaining greater yields become unprofitable.

To determine what the optimum combination of equipment will be we first assume that the size of the farm is fixed and that the farm operator has available the required resources to purchase and operate an optimum combination of equipment. It then becomes a matter of weighing the additional costs involved in the required change in the equipment combination.

3/ Unpublished Experimental Station data, Northwestern Montana Branch Station, Creston, Montana.

to bring about an increased yield against the additional returns to income from the increased yield (assuming a constant price for the product produced).

This concept can be applied more specifically to dryland conditions in Montana to determine what time limits must be met by the dryland spring wheat farmer.

Under dryland conditions in Montana the actual profitable working time on crops is limited to about 85 days per season. If we assume that dryland farms operate on the basis of an alternate crop and fallow system and that average weather condtions exist, the time limits in actual working days for the most effective results are as follows:4/

Planting		15 to 18 days
Fallowing -	First Operation	20 to 25 days
	Second "	10 days
	Third "	10 days
	Fourth "	10 days
Harvesting		15 days
TOTAL		80 to 88 days

The determination of what is an optimum combination with respect to time limits involves the determination of what operation is the limiting factor.

As an illustration we might use the operation of planting. The power units and size of equipment required to accomplish the seeding operation in 15 days might be considerably larger (special emphasis placed on the power unit) than what is required for the other farming operations. This

4/ E. A. Starch, Farm Organization as Affected by Mechanization, Montana Agricultural Experiment Station Bulletin No. 278 (May 1933), p. 29.

presents a problem of evaluating the gain in terms of yields and income of the faster seeding operation against the additional cost, if any, of owning and operating a larger equipment combination than is necessary to perform the remaining field operations.

Resource Substitution:[5]

The second aspect of maximizing net farm income is one of resource substitution in attaining a given level of production at a minimum cost.

Assuming that the amount of product to be produced is given, the farmer is concerned with how variable factors of production can be combined to produce a given amount of product at a minimum cost. Assume that two variable factors of production (X_1 and X_2) substitute for each other in the production of the given level of output. In other words, various combinations of the two inputs may be used to produce a given amount of product.

The various combinations of X_1 and X_2 which will produce Y_0 amount of product is indicated by "iso-product curve" Y_0. Therefore the slope of the iso-product curve Y_0 represents the "marginal rate of resource substitution."

To determine minimum costs, value concepts must again be used. If the total outlay (TO) available is given for the purchase of inputs and the total outlay available for the purchase of inputs is used entirely

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[5] For a more complete discussion of resource substitution and cost minimization, see Earl O. Heady, Economics of Agricultural Production and Resource Use, (New York, 1952) chapters 5 and 6.

for X_1, the amount of X_1 which can be purchased is indicated by $\frac{TO}{PX_1}$ in Figure 3. The point $\frac{TO}{PX_2}$ can be determined in an identical manner by using all available outlay for the purchase of X_2. The points $\frac{TO}{PX_1}$ and $\frac{TO}{PX_2}$ are joined by an "iso-cost" curve whose coordinates represent all possible combinations of the two inputs which can be purchased with the total outlay TO. The slope of this iso-cost curve (for purely competitive resource markets) is expressed as the ratio (PX_1/PX_2).

The optimum position or minimum cost combination is obtained where the slope of the iso-product curve is equal to the slope of the iso-cost curve ($\Delta X_2/\Delta X_1 = PX_1/PX_2$). This is indicated by point B in Figure 3 which denotes the use of OC amount of X_1 and OA amount of X_2.

Types of Equipment Costs:

It is essential at this time, before going into the problem of cost minimization and the study of the various choices available to the farmer to minimize costs, to classify and identify the various costs involved.

Machinery costs can be divided into two major classes: (1) fixed or overhead costs and (2) variable or operating costs. The overhead costs are depreciation due to obsolescence, interest on investment, taxes, insurance, and housing. These are also termed fixed costs, but this classification is relative. A machine decreases in value both from obsolescence and from use. Depreciation from obsolescence takes place whether the piece of equipment is in operation or not, but the decrease in value aside from obsolescence is more rapid when it is in use. Variable or