MONTANA STATE UNIVERSITY

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
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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.

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ECONOMIC CONSEQUENCES OF VARYING MACHINERY
COMBINATIONS ON DRYLAND SPRING WHEAT FARMS

by

PAUL ANDRILENAS

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TABLE OF CONTENTS

123698

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF ILLUSTRATIONS

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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/ E. 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.

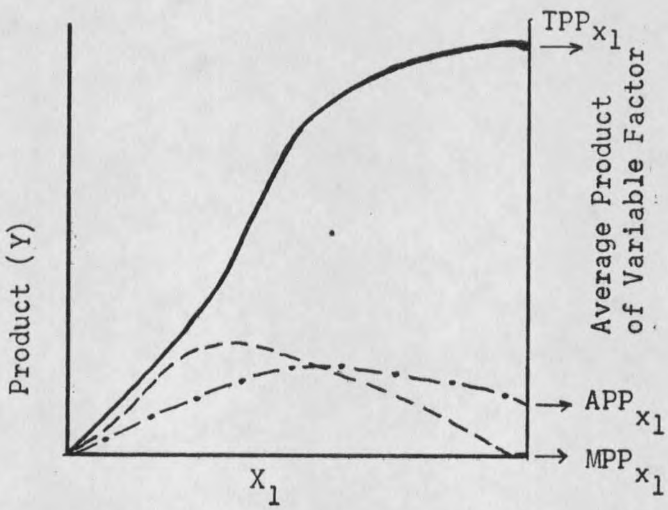

Figure 1. Input Variable Factor

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

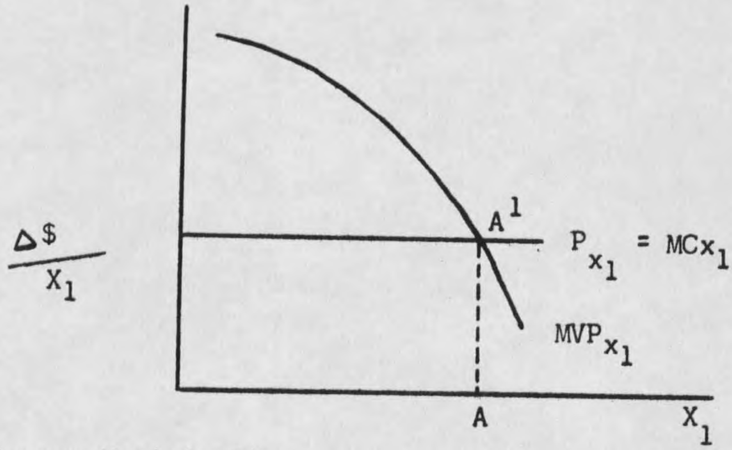

Figure 2. Income Maximization.

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

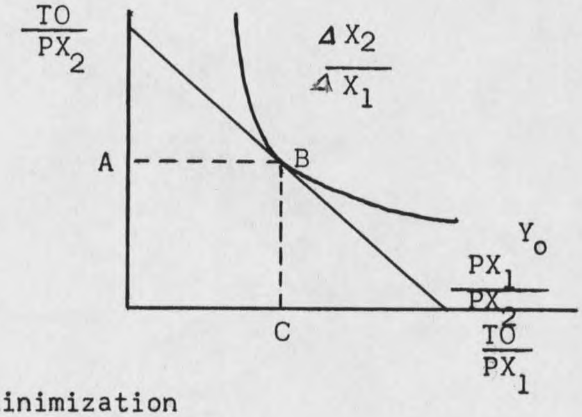

Figure 3. Cost Minimization

operating costs change in approximate proportion to the amount power equipment and machinery is used, and cease when equipment stops operating. This class of costs includes fuel, oil, grease, repairs, and labor.

The characteristics of the different costs are as follows:[6]

1. Depreciation (defined as the initial cost spread over the years of service. The loss in value and service capacity resulting from natural wear in use, obsolescence, accidental damage, rust, corrosion, and weathering.) is partly fixed and partly variable and varies with the life of the machine.

2. Since money used to buy a machine cannot be used for other purposes such as the purchase of land, livestock, or other enterprises, interest on investment should be charged for money invested in equipment. The interest on investment will be greater in the early life of a machine because an amount in total value is written off each year in the form of depreciation.

3. The repair cost, while not the largest of machine costs, is an important item of expense. It is a cash and labor cost for which the owner is liable at any time during the machine's life. The satisfactory performance of the machine depends to a considerable degree on proper and systematic repairing.

6/ F. C. Fenton and G. E. Fairbanks, op. cit., p. 27.

4. The cost of fuel and oil is a major item in the operating expense of tractors and combines. For tractors, the cost of fuel over the life of the tractor will usually exceed the initial cost of the tractor. In addition, many farm machines are operated with a tractor or auxiliary engine and the cost of the fuel should be included in the total machine costs. Lubrication is a minor item of expense.

5. Invariably, one or more men are required to operate most farm machines and any calculations of the cost of operating farm machines should include the labor costs.

6. Finally, such expenses as taxes, insurance, housing, should be included in the total operating expenses of farm machinery.

Discontinuous or Indivisible Factors:[7]

The foregoing discussion of cost minimization involves substitution decisions when resource units are infinitely divisible. (See Figure 3). Many items which appear discontinuous can be broken down into continuous inputs if the services [8] of the resource rather than the resource are considered. Essentially only the pure flow services, those services which are given off whether the machine is used or not, can be considered as indivisible. Stock services, those services which are given off only with use, can be considered as divisible over time. Current costs due to obsolescence do not lend themselves to divisibility, while stock services become divisible by varying the amount of machine used in different periods.

7/ For a complete discussion, see Earl O. Heady, Economics of Agricultural Production and Resource Use, op. cit., pp. 150-153.

8/ The elements embodied in a resource which may or may not become an integrated part of the product, but will produce a product or aid in the production of a product.

Although the farm operator cannot substitute one-half of a plow or tractor in his machinery combination, he does have choices to eliminate some of the indivisibility. Choices are available in the acquisition of machines which embody different amounts of services by buying those of different sizes, types and by hiring part of the machine services or varying the amount of labor.

If machine inputs are considered in the broader sense of machine services,[9/] it is possible to eliminate the discontinuity of machine inputs. Instead of considering machine services as discrete inputs, the discrete cases can be broken down by varying the sizes, types, quality, and amount of hired machine services used in the production of a given product. A continuous substitution rate of machine services for another factor of production can be obtained by substituting the elements of production obtained from machine inputs rather than the machine inputs themselves.

However, numerous situations exist where individual techniques or a limiting quantity of factor make it possible for machine services to substitute in the production of a given product only in discrete quantities.

Suppose one tractor and one man can farm 450 acres of spring wheat and the same tractor with two men can farm 750 acres of wheat. Two tractors with one man will not increase output because one man can

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9/ The elements embodied in machine inputs which will produce a product or aid in the production of a product.

operate only one tractor at a time. On the other hand, two tractors and two men could possibly farm 900 acres. The factor-factor relationships involved are illustrated in Figure 4.

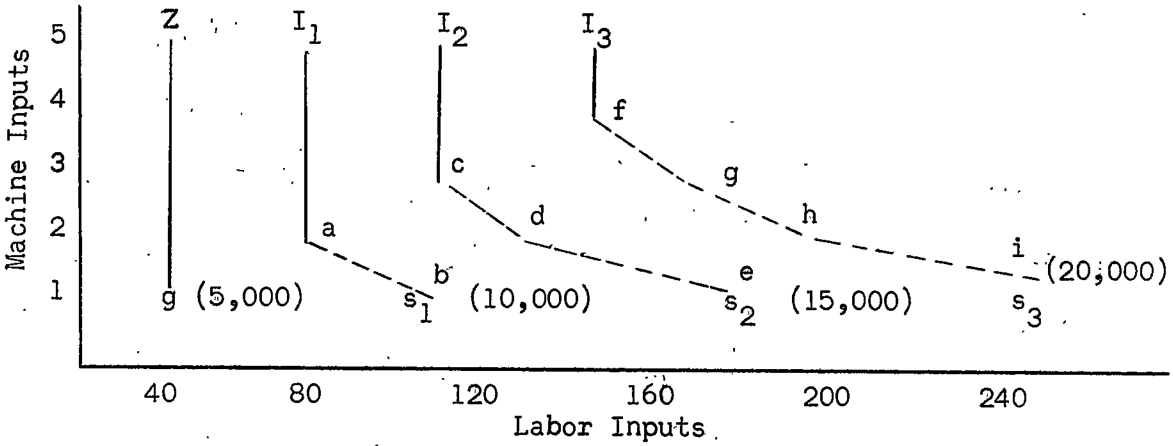

Figure 4. Resource Substitution with One Indivisible Factor

The vertical scale indicates machine inputs which can be added only in indivisible units of one. The horizontal scale indicates labor inputs which can be broken down into small fractions. The amount of labor required to operate the smallest machine input is forty units. An output of 5,000 bushels of wheat can be produced by one machine and forty units of labor. Additional machine inputs do not add to the output if labor is held constant as indicated by iso-product curve ZQ and as explained previously. Output of wheat can be increased 5,000 bushels by using 55 more units of labor as indicated by the line QS_1. Output again can be increased to 15,000 bushels by using an additional 65 units of labor (movement from S_1 to S_2). The movement along QS_3 being of the factor-product nature since machine inputs are fixed and labor is variable.

Machine inputs can be substituted for labor in producing the same amount of product as indicated by movement along iso-product curves I_1S_1, I_2S_2, and I_3S_3. For instance, in the production of 15,000 bushels of wheat (iso-product curve I_2S_2) the same amount of product can be produced by additional machine inputs. With one unit of machine inputs, 170 (point E) units of labor are required, but if another machine unit is added only 125 (point D) units of labor are required. A third addition of machine input would only substitute for 30 units of labor. A fourth unit of machine input will not substitute for labor and has a marginal product greater than zero only if labor is added as a complementary factor. The marginal rates of substitution of the second, third, and fourth machine inputs for labor in the production of 15,000 bushels of wheat are thirty-four, twenty and zero.

In the production of a given amount of product as indicated by iso-product curve I_2S_2 (Figure 4) when will the farmer substitute inputs of machine services for labor?

A shift to the use of machine inputs instead of labor will occur when the substitution ratio between machine services and labor is greater than the price ratios of the two factors. If the substitution ratio of the two factors is one unit of machine input for thirty four units of labor (line segment de Figure 4), a shift will occur when the price ratio becomes less than the substitution ratio. The solution can be stated in another way by saying, the slope of the iso-cost curve is greater than the slope of the iso-product curve (line de Figure 4) machine inputs will be substituted for labor.

Alternatives to Ownership and Use:

Essentially two other economic alternatives or choices exist whereby a dryland crop farmer can reduce costs pertaining to power equipment and machine use. Alternatives are available in the substitution (1) of custom-hiring of equipment services for actual ownership and (2) used for new machinery in the power equipment and machinery combination.

In the consideration of owning or hiring machinery, the machines which are most desirable to own are those which (1) obtain a low unit machine cost through high annual use and (2) have a low initial investment.[10]

Machinery and equipment which are used most are the ones a farmer can best afford to own. A substantial amount of machine costs are in the form of fixed costs. As the annual use increases, the annual cost per unit of output produced from their use declines if the requirements of timeliness are met. On an acre basis, the fixed costs decline in the manner indicated in Figure 5 with an increase in annual use when variable costs remain

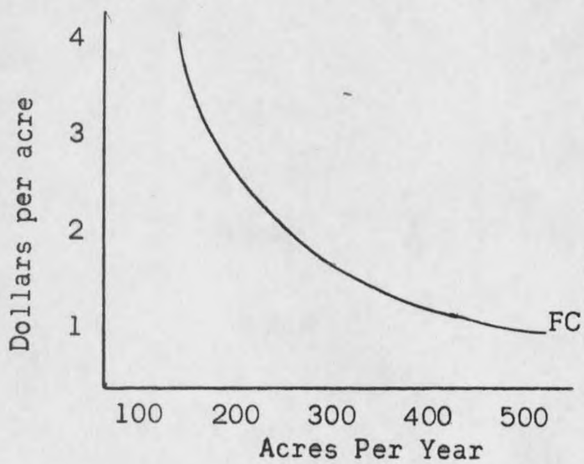

Figure 5. Fixed Costs

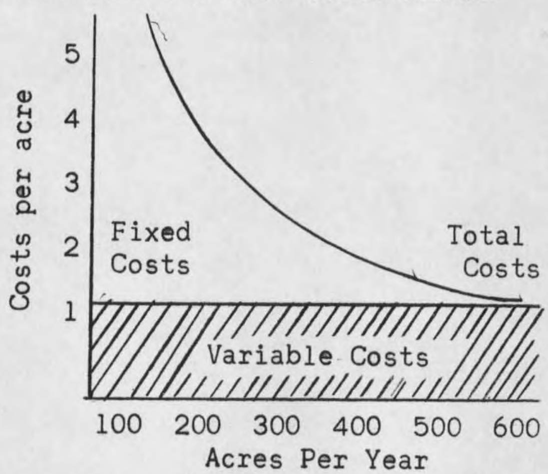

Figure 6. Total Costs

10/ Earl O. Heady and Harold R. Jensen, Farm Management Economics, (New York, 1954), p. 394.

relatively constant per acre. Therefore, total costs per acre are reduced as annual use increases (see Figure 6).

The amount of initial investment required to purchase a machine should be considered in making a choice between ownership or the hiring of machine services. The per acre cost of owning a machine of low initial investment is much less than one with a high initial investment due to the relationship of fixed costs to the amount of use. (As illustrated in Figure 5.)

Additional factors to consider, which favor the hiring of custom operators are: (1) a reduced capital investment in equipment; (2) freedom from such problems as servicing, reconditioning, and storage of equipment; (3) necessity of obtaining required financing for equipment; and (4) the ability to produce crops that require equipment which farm operators cannot afford to own.

The hiring of custom operators is not always the best decision and the preceding factors in favor of custom hiring should be weighed against factors which are unfavorable to dustom hiring. The factors unfavorable to custom hiring are: (1) not having equipment at the most opportune time; (2) disadvantages of an operator of a small farm bargaining with a custom operator; and (3) the additional cash costs of hiring custom operators.

The relationship between costs and annual machine use as it is associated with the hiring of machine services is illustrated in Figure 7.

It would be profitable for the farmer to hire a custom operator if the annual rate of use is such that the cost of owning and operating machinery is higher than the custom rates per acre. When the annual use of the machine is large enough the cost of ownership will fall below the custom rate and it would be more profitable to own the item of machinery. The point at which it would be more profitable to shift from custom hiring to ownership, as annual use increases, is indicated by point B in Figure 7.11/

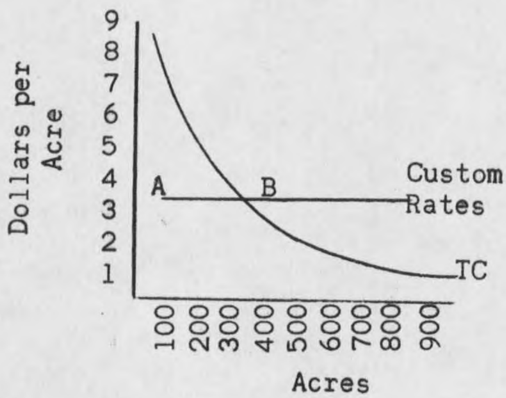

Figure 7. Relationship of Costs to Custom Hiring.

To the left of B the total cost per acre of owning a machine is greater than the custom rates charged. To the right of B the per acre costs of ownership drop below the prevailing custom rate making it more profitable to own rather than hire machine services.

Whether it is most profitable to own or hire machinery also hinges on the returns that can be obtained in investments other than power equipment and machinery. Even though investment in equipment would be more profitable than hiring custom operators, the percent of return could be less than the percent of return in some other alternative. If capital is scarce and higher returns can be obtained in another investment (such as livestock, fertilizer, etc.) greater profits are obtained by the hiring of machinery services.

11/ *Ibid*., p. 394.

Another economic alternative available to the farmer is the substitution of new or used machinery in the machinery combination.

The substitution of used machinery for new machinery in the machinery combination hinges upon a number of factors. The most important is the ability of the used machine in performing the required farming operation. It is quite imperative that the machine perform the required operations in a manner commensurate with accepted standards and costs. A used item of equipment would bring excessive losses and costs to the owners by heavy breakage and uncertainty of performance. Excessive repair costs would increase the farm operator's cash costs and losses in yields would occur through uncertainty of operation.

The purchase of a new or used machine buys a given amount of machine services. New machines tie up more capital and thus create a higher cost to the farmer than used machinery. As a result, the use of new or used machinery is based primarily on the amount of capital available and the opportunity rate of return in alternative investments. Consequently, it pays a farmer to buy used machines with services equal to those of a new machine when (1) the present cost of a used machine and (2) the future cost of used machines discounted at the opportunity rate of return to the present are less than the present cost of a new machine.12/

Suppose a farmer with limited funds has a choice of buying a new tractor for $3,800 or a used one for $2,400. The new tractor has an estimated life of 12 years with an annual depreciation of $316. The used one is

12/ Ibid. p. 396.

expected to last another six years, with an annual depreciation of $400. If the two tractors have no significant difference on the quality and quantity of production, which investment would be the most lucrative for the farmer? Will the new tractor which costs $1,900 more but has an annual cost of $84 less be a better purchase than the used machine which has to be replaced in six years? To purchase the used tractor would mean that $1,900 is available for investment in another alternative. Hence, returns on these investments may more than offset the higher annual costs on the used power unit, whereby, the real cost of investing in the new machine is the opportunity cost.

A choice exists between investing $3,800 in a new tractor with the equivalent of 12 years' service and $2,400 in a used power unit and an additional $2,400 six years hence to obtain a service life equivalent to that of a new tractor. If the farmer can earn ten percent by investing his capital in some other way (such as livestock, fertilizer, etc.), what amount invested today will grow into $2,400 in six years to replace the used tractor?

To calculate the present value of the cost, an equation used by Heady and Jensen is appropriate. The equation can be stated as $PV = \frac{q}{(1 + r)}n$; PV refers to the present value of the future amount, q is the future amount, r is interest rate and n refers to the number of years into the future with which we are concerned.[13]

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[13] Ibid., p. 87.

Substituting in the equation we get:

$$PV = \frac{2,400}{(1.10)6} = \frac{2,400}{1.7715} = \$1,354$$

To provide 12 years of tractor service from used machines $2,400 is invested now in a tractor plus $1,354 invested elsewhere at 10 percent to provide for a second tractor at the end of six years or $3,754.

This amount is $46 less than the $3,800 present cost of the new tractor. Accordingly, when returns in alternative investments are 10 percent, the used tractor is the least costly.

Also consideration should be given to a farmer with ample capital who has a choice between buying a new tractor or a used tractor. Because he has an adequate supply of funds, he has invested in his farm business until no alternatives for high returns are available.

Assuming the same choice is available between a $3,800 new tractor and the $2,400 used tractor, what would be the most profitable alternative? If capital can be invested in some other alternative for only 5 percent how much must be invested to purchase a second used tractor at the end of six years?

Substituting again in the equation $PV = \frac{a}{(1 + r)^n}$ we obtain:

$$PV = \frac{2,400}{(1.05)6} = \frac{2,400}{1,340} = \$1,791$$

To provide 12 years of tractor service from used machines, $1,791 is invested elsewhere at 5 percent to provide for a second tractor at the end of six years of $4,191.

This amount is $391 more than $3,800 present cost of the new tractor. Accordingly, when returns in alternative investments are 5 percent, the new tractor is the least costly.

Limitation of Problem:

In this problem an important group of cost relationships associated with power equipment and machine use are not considered. Due to the unavailability of empirical data, it was impossible to test the economic alternatives related to the use of various sizes of machines with a given size of tractor. Machinery inventories, taken from the sample of farms used in this study, revealed a great deal of uniformity in the size of equipment used with a given size of tractor.

The two basic sizes of tractors found were the 4-plow and the 5-plow. With each size of tractor, the size of equipment used was very uniform. Cases are few where machinery normally used with 4-plow tractor is used with 5-plow tractor or machinery normally used with 5-plow tractor is used with the 4-plow tractor.

This uniformity in machinery combinations made it impossible to obtain accurate performance rates and fuel consumption rates on tractors used with various sizes of farm equipment.

Primarily, economic alternatives considered are limited to those associated with the use of a tractor with a given size of machinery. The same size of machinery combination is studied relative to different sizes of farms, and cost relationships are determined on this basis. In addition, the most popular sizes of harvesting equipment are related to given acreages to determine the total, fixed, and variable costs relative to different amounts of annual use.

Problem Statement:

In considering that a large percentage of the costs relative to total costs in a dryland farming operation are associated with farm machinery, the economic alternatives available to dryland farmers in power equipment and machine use are very important. These alternatives will be important considerations for a farmer attempting to maximize net farm income.

To maintain net farm income, dryland farmers are concerned with machinery combinations which will reduce losses from climatic conditions by meeting timeliness of operation requirements. Machinery combinations must have an adequate daily capacity to perform the various field operations within time restraints to prevent excessive losses in yields and income.

This study also deals with the problem of factor-factor substitution in the production of a given product, whereby the substitution ratio between machine services and labor are equated to the price ratios, inversely, of the two factors. Assuming that the amount of product is given, the farmer is concerned how variable factors of production can be combined to produce a given amount of product at a minimum cost.

The problem also hinges upon the alternatives to ownership and use associated with the substitution (1) of different sizes of equipment, (2) used for new machinery, and (3) custom hiring for actual ownership in the machinery combination. From these substitution alternatives, relationships of fixed costs to variable costs are determined relative to different amounts of use.

METHOD

Budget Analysis:

The budget analysis will be used to study the economic alternative in power equipment and machine use availabe to the farm operator. The primary purpose of the budget is to compare the cost relationships between different sizes of machinery combinations and custom hiring and ownership of machinery. The budget can be used as a descriptive device in terms of which to synthesize an average or representative situation or an analytical technique for comparing returns from alternatives associated with a given farm.

Use of Synthetic Model:

Synthetic models are used to permit freedom in combining proudction resources and practices so that managerial ability and efficiency are similar for all farms included in the average. The models are used to fix many of the variables found under actual conditions in order to determine the influence of the variable factors under study.

The budgetary technique begins with a given situation in the form of a synthetic model. Changes are introduced and the results are measured in terms of changes in expenses. In this way the impact of alternatives in power equipment and machine use on the total farm business can be estimated.

Short-Cut Budgets :

Use of the budget technique is so time-consuming that only a few of the more important variables can be tested. To increase the number of variables which can be tests, "short-cut" budgets are used. An analysis will be made by partial budgets to estimate cost changes to that part of the farm business directly concerned.

PART II

DATA

AREA

The study concerns type-of-farming areas III and IV in northeastern Montana, approximately 175 miles from north to south and 80 miles from east to west.

The topography is characteristic of a glaciated area: high plateaus with more or less gravelly and eroded slopes, terminal moraines, valley benches, and breaks along the larger streams. The average elevation is approximately 2,500 feet, varying from less than 1,900 feet along the Missouri and Yellowstone River to approximately 3,100 feet on the higher plateaus.

Average annual precipitation is fourteen inches. Precipitation during growing season (April to September) is ten inches. The average number of days without a killing frost is 120 days.[1]

The area was originally a ranching area, but with the coming of the railroads, became predominately a dryland farming area. Good years and better prices in the period 1922-25 set the stage for a shift to mechanized farming. With the introduction of satisfactory power equipment, fewer and larger farms developed, the number of horses declined, and the acreage in cash crops increased. So also did the out-of-pocket expense in grain production.[2]

1/ Climate and Man, Yearbook of Agriculture, U. S. Dept. of Agriculture, (Washington, D. C.: U. S. Government Printing Office, 1941), p. 964.

2/ Marion Clawson, M. H. Saunderson, Neil W. Johnson, Farm Adjustments in Montana, Study of Area IV: Its Past, Present, and Future, Bul. 337, Montana State College, Agr. Exp. Station, Bozeman, Montana, January, 1940, p. 10.

Area III is bordered on the north by the Missouri River and on the east by the State of North Dakota. It includes the entire area of Richland, Dawson, and Wibaux counties and parts of McCone, Prairie, Rosebud, Custer, and Fallon counties. The area is predominately a low-grade dryland farming and ranching area, bisected by the Lower Yellowstone irrigation project. Alfalfa, sugar beets, and feed grains are grown in the irrigated areas. Dryland grain production continues as a major enterprise over much of the area.

Area IV is bordered on the north by Canada and on the east by North Dakota. It includes the counties of Sheridan, Roosevelt, and Daniels, and also the eastern portion of Valley county. Area IV is one of the two major wheat producing areas of Montana. Soils are good, but a great variability exists in wheat yields.

Area IV is characterized by high density of wheat production, relatively good quality soils, and intermixture of soil types. Area III differs from Area IV in that the former has a much lower percentage of good farming soils. Cash grain farms are the most numerous type of farming operation in both areas. But ranches are more numerous and important in Area III than in Area IV.[3]

THE PRIMARY DATA

The primary data used in the study were obtained from two surveys. The first was of farmers selected in type of farming Areas III and IV. The second was of machinery dealers serving these farmers. Thirty-five

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3/ Ibid., p. 5-8.

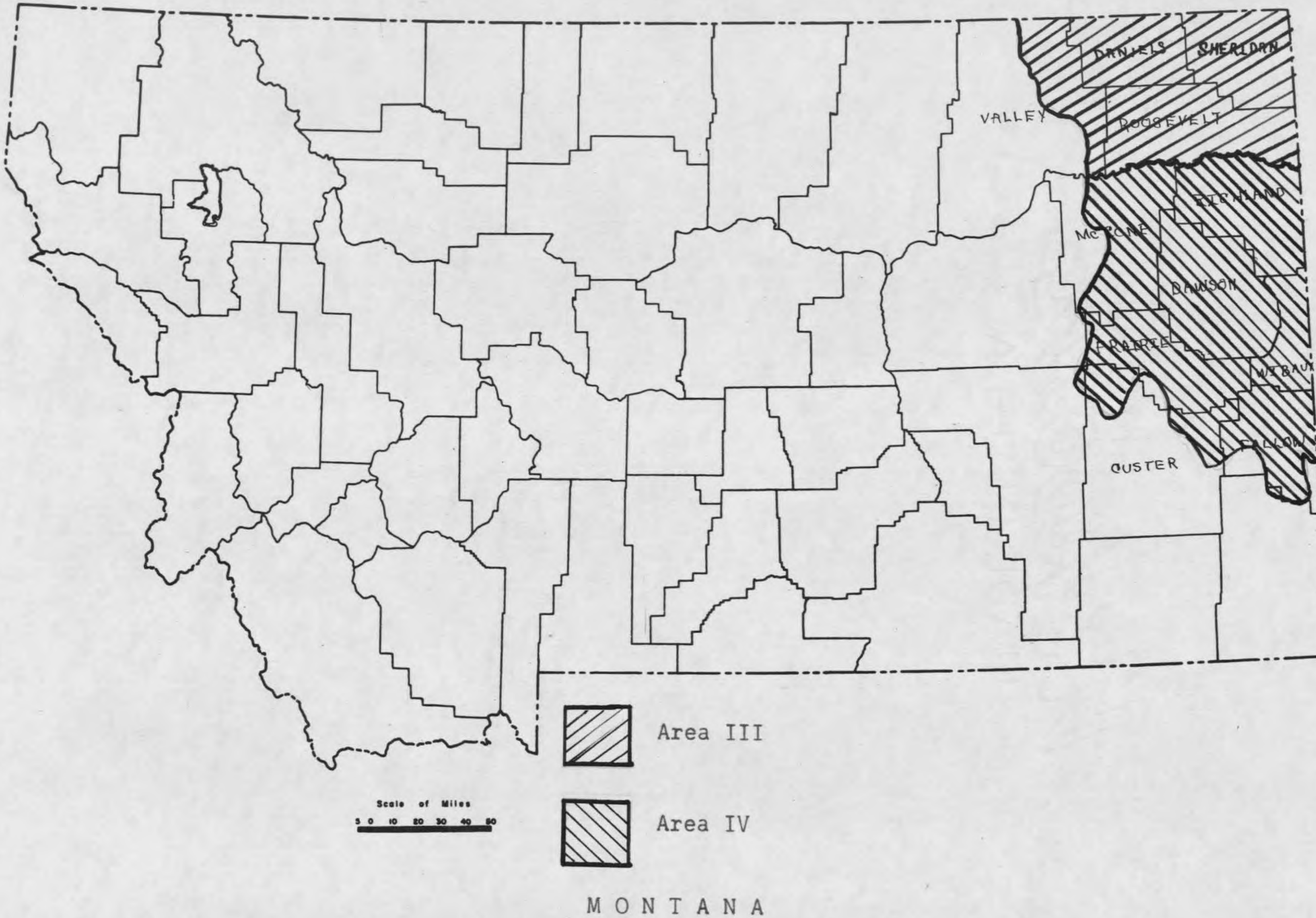

Figure 8. Study Area.

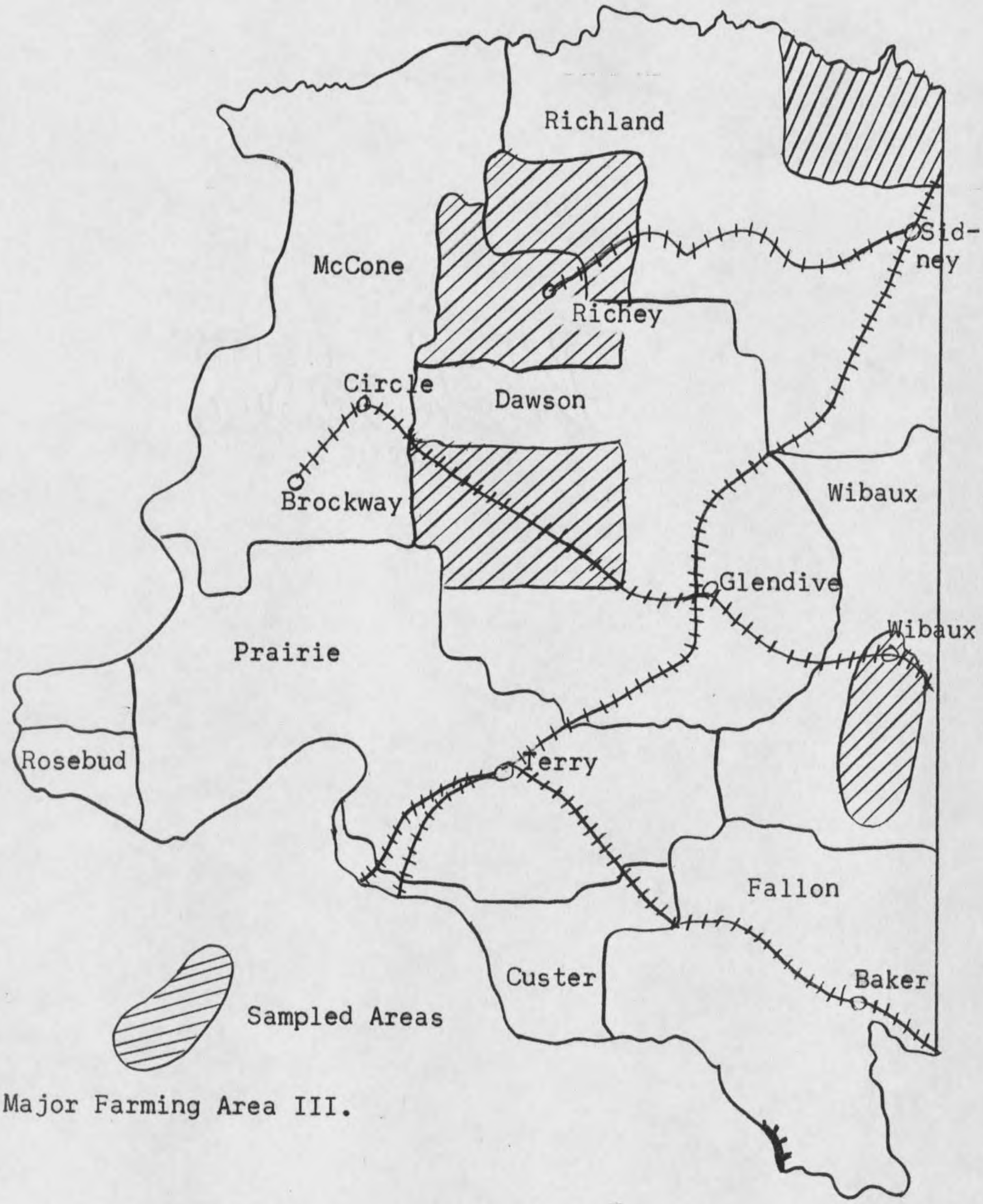

Figure 9. Major Farming Area III.

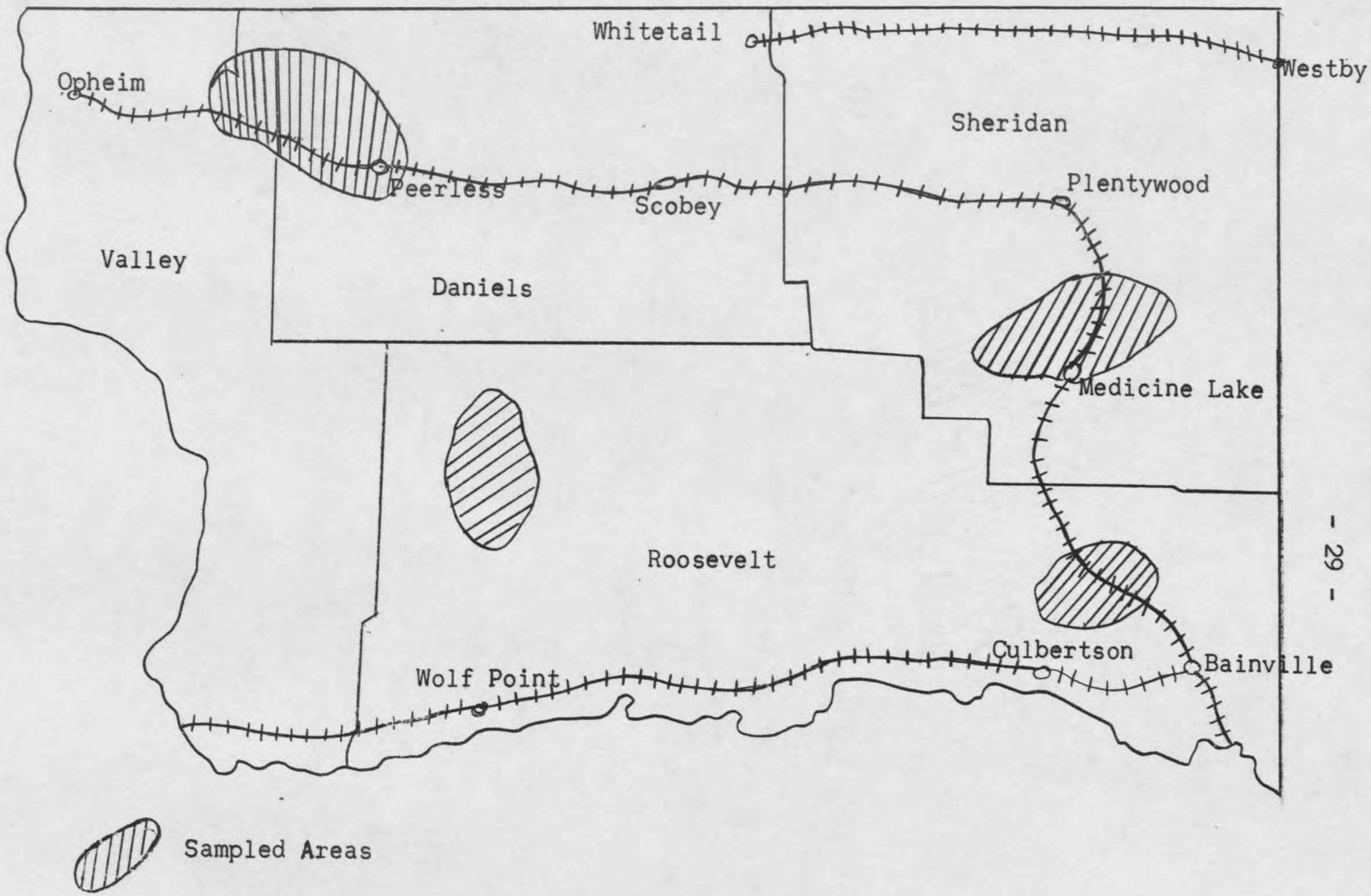

Figure 10. Major Farming Area IV.

farm operators were interviewed in communities made up of specialized dryland spring wheat farms. The survey was designed to discover economic alternatives in power equipment and machine use on dryland crop farms in northeastern Montana. The sample was drawn from ASC farm lists according to size, in acres, to get a representative number of farms in the small, medium and large acreage classification of farms.

These data were used to compute typical performance rates, fuel consumption rates, together with labor, lubrication, and repair costs pertaining to various sizes and types of power equipment and machinery used in a spring wheat farming operation. The information obtained from this sample of dryland farms also made it possible to determine the sequence of farming operations, typical enterprise organization, the availability of labor, and the typical machinery inventory. Nine implement dealers were selected in a non-random sample. They were found in seven different towns and represented five different makes of farm equipment. The dealers were chosen to be representative of the trading area in which the interviewed farmers purchased their equipment.

The information acquired from dealers made it possible to obtain averages with respect to prices charged for various types and sizes of farm equipment. Furthermore, data were acquired for computing the average length of life of machines, values allowed on trade-ins, and the types and size of predominate equipment being purchased by farm operators.

The sample data are characterized by two shortcomings: (1) faulty memory of farmers interviewed in the sample and (2) small size of sample in view of large variations found in observed items.

The information was gathered in the early summer of 1955 for the 1954 production period. Therefore, many of the cost estimates given are not wholly accurate. Such items as repair costs for individual items of equipment are not accurately separated out of the total repair costs. Farmers are unable to associate certain minor repair costs specificially to a particular item of machinery. However, for such estimates as the performance rates associated with various field operations, the change is not significant from year to year and the estimates are considered to be reasonably accurate.

Due to the fact that a few farmers were interviewed over a large area, a large deviation in one case, because of unusual conditions, can strongly affect the computed statistics. For many sizes of equipment, only a few cases exist within the sample and a marked variation of one case relative to the others would give a large standard error in the relevant statistic.

However, the major items of equipment used in dryland farming operations are relatively uniform as to size and capacity in performing field operations. This uniformity among major items of equipment made it possible to obtain a large number of cases from the sample for computing accurate performance rates, fuel consumption rates, and costs per acre.

THE FARM ORGANIZATION

The selection of sizes of farm sizes used in the budget analysis were selected at modal and mean values of a frequency distribution of sizes measured in acres.

To obtain a more representative frequency distribution, the original sample of thirty-five farms taken in the universe was supplemented by another sample of forty-two farms. Originally, this second sample was used by the Production Economics Research Branch, Agricultural Research Service, U. S. Department of Agriculture in a diverted wheat acres study. The random sample was taken to determine the changes brought about by acreage allotments in the dryland spring wheat area of northeastern Montana. The supplemental sample was drawn from the same geographical area and represented farms with the same characteristics in respect to kinds of crops grown and types of farming operations.

The eighty-seven farms were arrayed by crop acres in class intervals of two hundred acres until the farms reached an acreage of 1,600 acres of cropland. In the upper ranges of the series the size of the classes are increased to reduce the number of classes and increase the usefulness and significance of the classes (see Figure 11). This frequency distribution shows some tendency to be bi-modal at the 2,000 - 2,999 acre classification. The largest number of farms fell in the 400 - 599 acre group with a mode value of 550 acres. The mean of the distribution was 944 acres. The second mode fell in the 2,000 - 2,999 acre class at 2,344 acres.

In the budget analysis, the 550 acre farm was designated as the small farm, the mean farm (944 acres) as the medium farm, and the 2,344 acre farm as the large farm to be used in testing out economic alternatives in power equipment and machine use.

Enterprise Organization:

The cropping system used in this study is limited to a two-year spring wheat and summerfallow rotation. Table I indicates the acres of cropland and summerfallow found on the 550, 944, and 2,344 acre farms used in the

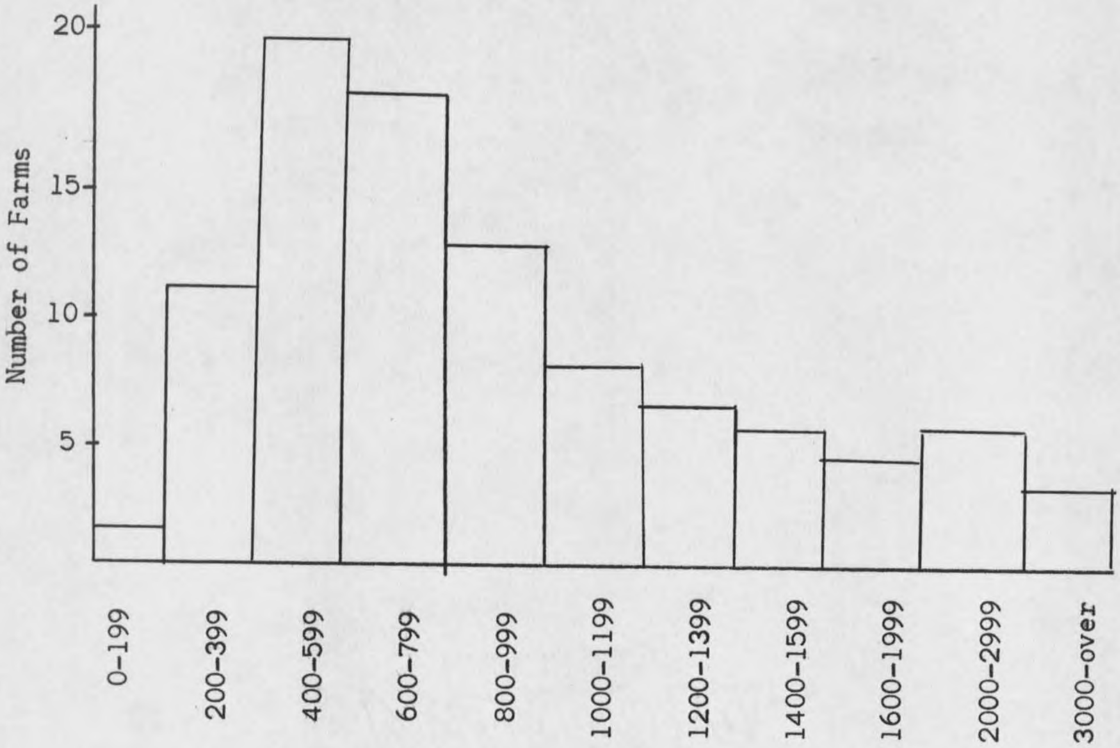

Figure 11. Frequency Distribution by Acres of Cropland for a Sample of 87 Spring Wheat Farms.

budget analysis. The wheat-summerfallow rotation is the type of rotation predominately used in the spring wheat area of northeastern Montana. Variations occur, but are essentially based on this type of crop rotation.

In a few instances a three-year rotation is practiced on a small part of the farm, but these instances are restricted to a few small farms and farms with large numbers of livestock with respect to crop acres.

Livestock numbers are few. They do not have a marked effect on the basic machinery combination used in the dryland crop rotation. If large numbers of livestock are present, the machinery combination used in crop

TABLE I. CROP ORGANIZATION OF 550, 944, AND 2,344 ACRE FARMS USED IN THE BUDGET ANALYSIS.

Size of Farm	Acres in Crop	Acres in Fallow
Small (550 acres)	275	275
Medium (944 acres)	472	472
Large (2,344 acres)	1,172	1,172

operations is supplemented by another component of equipment used in the livestock enterprise. A smaller tractor with the related haying and forage handling equipment is usually present in the machinery inventory. Furthermore, if livestock are present in small number, they do not have a significant effect on decisions pertaining to power equipment and machinery. The basic cash grain crop still remains the influential factor in farm machinery decisions.

To eliminate all forms of livestock from the farm organization and to limit the cropping system to a wheat-summerfallow rotation does not give a completely typical farm (see Appendix I), but it does serve as a simpler way of obtaining the desired results. Essentially the other production alternatives available to a dryland farmer are feed and oil crops such as barley and flax. But these crops require about the same type of equipment for planting, tillage, and harvesting. The costs, performance rates, and power requirements for all practical purposes remain the same and do not alter farm machinery decisions.

With present wheat acreage regulations the dryland farm operator is using the wheat-fallow rotation in a more rigid manner than in previous years. If the wheat allotment is inadequate, barley is added as an enterprise alternative with a goal of planting at least half of the crop acres.

Resources:

Labor

The supply of labor found on these dryland crop farms is relatively stable. The majority of the labor supply is in the form of family labor provided by the farm operator and is available the year around. Sample data show that, for farms within the 400 - 599 and 800 - 999 acre classifications, the farm operators provide 30 days of available labor each month over the entire year. In the 2,000 - 3,000 acre classification, the amount of available labor provided by farm operators increases during the months of March through October. On the larger farms the sample of farmers indicate that a portion of the farm operators go to the city to live during the months of October through February. In addition, the larger farms are characterized by having two men who act as co-managers, often fathers and sons or brothers are associated together and actively provide labor for the various farming operations.

Table II indicates the average number of days of labor available per farm in the specified acreage classifications wherein the 550, 944, and 2,344 acre farms lie.

The peak months for hiring labor on farms in 400 - 599 acre classification are April through May and the middle of July to the middle of August. On medium farms (800 - 999 acres), the peak occurs in the months of April, May, and August. Finally, for farms falling within 2,000 to 2,999 acres, the amount of labor hired is quite uniform from April through September.

TABLE II. AVAILABLE LABOR SUPPLY OF LABOR PER FARM PROVIDED BY THE FARM FAMILY.

Size in Crop Acres	Average Number of Days of Available Labor per Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
400 - 599	30	30	30	30	30	30	30	30	30	30	30	30
800 - 999	30	30	30	30	30	30	30	30	30	30	30	30
2,000-2,999	30	30	45	45	45	45	45	45	45	30	30	30

Machinery

All machinery listed in Tables III and IV are typical combinations of machinery found in the sample data which would correspond as closely as possible to the 550, 944, and 2,344 acre farms. The sample data were arrayed for farms in the 400 - 599 acre group to determine a typical machinery combination for the 550 acre farm. From this array, the modal size of each particular type of farm machinery was determined as a part of the typical machinery combination. The modal size for each type of machine and the average number of the modal size of machine most frequently used in planting, tillage, and harvesting on the sample farms was considered as part of the typical machinery combination. These modal sizes from each acreage group, by types for a given farming operation, make up the typical machinery combination.

The same procedure was used for farms within the 800 - 999 acre group to determine the typical combination for the 944 acre farm; and for the farms within the 2,000 - 2,999 acre group, to provide the modal sizes for the 2,344 acre farm.

TABLE III. TYPICAL MACHINERY COMBINATIONS FOUND ON FARMS CLASSIFIED WITHIN 400 - 599 ACRE GROUP AND THE 800 - 999 ACRE GROUP.

400 - 599 acres		800 - 999 acres	
Implement	Size	Implement	Size
Tractor (gasoline)	5 plow	Tractor (diesel)	5 plow
Tractor (gasoline	2 plow	Tractor (gasoline)	4 plow
Drill (press)	12 foot	Drill (press)	12 foot
Duckfoot (cultivator)	12 foot	Duckfoot (cultivator)	12 foot
Oneway disc	8 foot	Oneway disc	10 foot
Tandem disc	10 foot	Tandem disc	10 foot
Plow	3-14" bottoms	Plow	4-14" bottoms
Toolbar	12 foot	Toolbar	12 foot
Combine (self-propelled)	14 foot	Combine (self-propelled)	14 foot
Mower	7 foot	Rodweeder	12 foot
Hay rake	12 foot	Mower	7 foot
Grain auger	27 foot	Hay rake	12 foot
		Grain auger	27 foot

A comparison of the typical machinery combinations found upon the small and medium sized farm indicate a great deal of uniformity in types of equipment used. Excluding differences in size, the medium-sized farm has a 12-foot rodweeder and a 5-plow diesel tractor in the machinery inventory which are not found on the small farm. With respect to size, the second tractor on the small farm is a 2-plow in comparison to a 4-plow on the medium sized farm. The oneway disc and the plow are larger on the medium-sized farm.

A substantial difference exists in the machinery inventories between the large farm and the medium farm. The large farm tends to have two items of equipment where the medium size farm has one or one item of equipment which is larger in size.

TABLE IV. TYPICAL MACHINERY COMBINATIONS FOUND UPON FARMS CLASSIFIED WITHIN THE 2,000 - 2,999 ACRE GROUP.

2,000 - 2,999 acres		
Implement	No. per Farm	Size
Tractor (diesel)	2	5 plow
Drill (press)	2	12 foot
Oneway disc	1	16 foot
Tandem disc	1	10 foot
Plow	1	5-14" bottoms
Toolbar	1	13 foot
Combine (self-propelled)	2	14 foot
Rodweeder	2	12 foot
Mower	1	7 foot
Hay rake	1	12 foot
Grain auger	1	27 foot

Practices:

Field Operations

The field operations can be divided into three groups: (1) planting, (2) summerfallowing, and (3) harvesting. Planting and harvesting are essentially one-time operations while summerfallowing, on the average requires tillage at least three times during the growing season.

Planting is usually accomplished by pulling several implements in tandem behind a tractor. The two most widely used implements are the duck-foot or toolbar cultivator and a press drill. Other combinations used are the tandem disc and drill, the oneway disc and drill, and the rodweeder and drill.

The tillage implements (discs, rodweeders, and cultivators) are pulled in front of the drill to destroy any small weeds and prepare the seedbed for planting. The type of tillage implement used depends upon the condition of the seedbed, whether it is free of trash, and the size of the weeds at the time of planting. Discs are used primarily if the ground is trashy or the weeds are relatively large.

A variety of tillage implements are available to perform the summerfallow operations on a dryland crop farm. The selection depends upon the moisture conditions, 1st, 2nd, or 3rd summerfallow operations, amount of trash, and type of soil.

In the first summerfallow operation of the year, the oneway disc is used most extensively. Except for unusual situations, this implement has replaced the moldboard plow in the initial summerfallowing operation of the year. However, recent developments in sub-surface tillage equipment has detracted from the importance of the oneway disc.

The remaining summerfallow operations can be accomplished by a number of tillage implements. But the duckfoot and toolbar cultivators are still the most widely used type of tillage equipment.

Where conditions are favorable the rodweeder is considered as a desirable type of tillage implement. The rodweeder has an advantage over other implements because of its light draft and low operating costs per acre. The fact that the rodweeder does have a light draft makes it possible for tractors to travel at higher speeds or pull a greater width of implement thereby covering a larger number of acres in a day relative to other types of tillage implements.

The actual harvesting operation is performed by self-propelled combines. Information obtained from farmers and implement dealers indicated that relatively few pull-type combines are in use and few are being sold to farmers by implement dealers.

Efficient Combination of Land and Equipment

The best combination of land and equipment for a dryland unit is conditioned largely by investment in equipment and the time limit for field operations. The starting point from which this combination could be determined is the number of days allowed by climatic conditions for the various field operations. The loss in income through reduced yields makes it unprofitable to extend the performance of a field operation beyond certain time limits. The number of acres to be covered, divided by the number of days in which the job should be done, gives the daily capacity which is required of the machinery.

However, in this study, the problem was approached by taking the estimated daily capacity of machinery and dividing it into the number of acres to determine if a particular size of machine meets the timeliness of operation requirements. The average performance rate estimates used were farmer estimates obtained from empirical data. These estimates are used to fit an equipment combination to the 550, 944, and 2,344 acre farms.

The time limits for performing the various field operations under Montana dryland conditions are as follows:

		Approximate Calendar Dates
Planting	15 days	April 10-30
Fallowing		
First operation	25 days	May 1-30
Second operation	10 days	June 15-30
Third operation	10 days	August 1-15
Harvesting	15 days	Aug. 15-Sept. 5
Total	75 days	

These time limits are actual working days of ten hours per day. It is assumed that losses in time due to rain or other factors can be made up by longer shifts and night work.

The normal seeding date, in the area studied, is April 15. Planting must be accomplished within fifteen days from this data to avoid losses in yields. Immediately after planting, the first summerfallow operation must be performed. This would specify the last week of May as the time of completing the first summerfallow operation. The remaining two summerfallow operations must be performed quickly, at intervals of approximately thirty days. Harvesting normally begins between August 15 and 20.

Critical periods in performing the field operations occur in May and August. As June is characterized by heavy precipitation, the planting and first summerfallow operation must be accomplished before the first week of June to avoid delays due to weather conditions. If summerfallow operations are required at approximately thirty-day intervals, a critical period will develop in August. The third summerfallow operation will be required by the first of August and it must be completed before harvesting starts on August 15.

POWER AND MACHINE EXPENSES

Variable Costs:

Variable costs make up a large percentage of the costs of using power equipment and machinery. The relative proportion of the total costs which are variable are dependent upon the amount of annual use. Basically, for a given size of farm implement, variable costs increase relative to fixed costs as the annual use increases.

Labor is an important factor in the determination of alternatives finally used in an equipment combination. If the supply of labor is ample and the cost per acre is low, the farm operator can best afford to invest in smaller implements and equipment. Smaller sizes of equipment do not have as large a fixed cost per acre and labor can be substituted for capital investment by using the machinery a larger number of days on a given acreage. Also, if the amount of capital is limited and the labor supply is ample, the supply of labor can be utilized as a substitute for a limited supply of investable capital.

On the other hand, if the labor supply is limited and its being fully used, additional work can be accomplished by investment in equipment with a larger capacity. If ample capital is available and the annual use of equipment is high, the capital investments in machinery can reduce costs by substituting them for the variable costs of labor.

In this study labor was priced at one dollar per hour for non-harvest operations. To determine the costs per acre of labor, the hourly rate was divided by the average acres per hour of different sizes and types of implements. This procedure gave a per acre cost of labor for each field operation. Hourly wage rates in the harvesting operation were set at the higher rate of two dollars an hour. The higher rate was considered necessary by farm operators to obtain the skill and dependability required in combine operators.

Fuel, oil, and repair costs are computed averages obtained from primary data. Empirical data obtained from sample schedules were arrayed according to different types and sizes of equipment. From this array, average per acre costs for fuel, oil, and repairs were computed (see Table V).

To obtain more representative average costs for the operation of individual items of farm equipment, data from the spring wheat area were supplemented by similar data from the winter wheat area of central Montana. The Production Economics Research Branch, Agricultural Research Service, U. S. Department of Agriculture conducted a similar study in the winter wheat area. The same schedule was used and the sample of farmers performed the same type of field operations. Also the type and sizes of power equipment and machinery were similar. The primary difference between the two sample areas was the type of wheat grown. However, the performance rates of the size and type of implements used in this study were comparable. Although the growing of winter wheat made it necessary to perform various farming operations at different times of the year, the data used supplemented the data obtained from the spring wheat area. The planting of winter wheat in the fall and the harvesting of winter wheat in the summer does not detract from the value of cost figures for specific items of farm machinery for purposes of this study.

Fixed Costs:

The next group of costs to consider are the fixed costs (depreciation, interest on investment, taxes, and insurance). These remain constant regardless of the amount of use.

TABLE V. COSTS PER ACRE OF VARIOUS TILLAGE OPERATIONS BY IMPLEMENT SIZES WITH GAS AND DIESEL TRACTORS AND SELF-PROPELLED COMBINES.

Item	Aver. A. Covered	Aver. A. Per Hr.	Aver. Fuel Per Hr.	Fuel Per A.	Oil Cost Per A.	Mach. Rep. Per A.	Trac. Rep. Per A.	Labor Per A.	Totals
			gals.	cents	cents	cents	cents	cents	cents
Oneway									
8' (gas)	477	2.9	2.3	18.0	1.8	2.8	10.8	34.5	67.9
(diesel)	477	2.9	2.3	14.1	1.8	2.8	10.8	34.5	64.0
10' (gas)	528	3.8	3.	18.1	1.4	3.6	7.9	26.3	57.3
(diesel)	528	3.8	2.5	11.8	1.3	3.6	7.9	26.3	50.9
Duckfoot									
12' (gas)	787	4.7	2.4	11.2	1.3	6.1	7.7	21.2	43.8
(diesel)	787	4.7	2.6	9.4	1.0	6.1	7.7	21.2	44.4
14' (gas)	971	5.6	2.	8.4	1.1	5.0	6.6	17.9	39.0
(diesel)	971	5.6	2.25	6.8	.8	5.0	6.6	17.9	37.1
Rodweeder									
12' (gas)	460	5.1	2.0	9.0	1.03	4.8	5.1	19.6	39.53
(diesel)	460	5.1	2.6	7.06	1.03	4.8	5.1	19.6	39.7
24' (gas)	692	10.2	3.2	7.2	.6	4.8	3.2	9.8	25.6
(diesel)	692	10.2	3.2	5.7	.5	4.8	2.8	9.8	23.6
Drill & Duckfoot									
10' (gas)	224	3.2	2.5	17.9	1.6	8.3	7.1	31.2	66.5
(diesel)	224	3.2	2.7	13.3	1.42	8.3	5.0	31.2	59.2
12' (gas)	559	4.2	3.1	17.4	1.3	8.7	7.2	53.8	58.4
(diesel)	559	4.2	2.6	11.1	1.2	8.7	6.1	23.8	50.9
Drill & Rodweeder									
12' (gas)	235	3.4	2.6	17.6	1.0	7.4	5.4	29.4	60.8
Self-propelled Combine									
12'	357	3.9	3.27	18.4	1.5	46.		52.	117.9
14'	427	4.4	3.2	16.	1.4	25.5		46.	88.9
16'	532	4.8	4.2	19.2	1.1	32.1		41.	93.4

The interest rate chargeable to machinery investment is more or less an arbitrary figure. The economically relevant interest rate would reflect the opportunity costs of alternative investments for the operator. For purposes of this study the approximate current interest rate of six percent was used for computing interest on investment costs. An additional two percent was added for tax and insurance costs.

The total cost of interest on investment, taxes, and insurance was calculated by taking eight percent times one-half of the original value. These costs are shown in Table VI.

TABLE VI. ESTIMATED LIFE, ORIGINAL PRICE, AND INTEREST, TAX, AND INSURANCE COSTS ON SELECTED ITEMS OF FARM MACHINERY.

Item	Size	Estimated Life in Years	Original Price (dollars)	Interest, tax, and insurance costs per year
Tractor	4-Plow (gas)	13	3,082	$123.28
Tractor	4-Plow (diesel)	13	3,874	157.84
Tractor	5-Plow (gas)	13	3,744	149.76
Tractor	5-Plow (diesel)	13	4,819	192.72
Drill	10 foot	10	761	30.48
Drill	12 foot	9	823	32.96
Oneway	8 foot	7	752	30.08
Oneway	10 foot	7	836	33.44
Duckfoot	12 foot	15	575	22.96
Duckfoot	14 foot	15	692	27.68
Rodweeder	12 foot	15	428	17.12
Combine (self-propelled)	12 foot	12	5,044	201.76
Combine (self-propelled)	14 foot	12	5,558	222.32
Combine (self-propelled)	16 foot	12	6,273	250.88

Depreciation:

Calculating depreciation costs presents a problem in determining what losses in value are due to use and what losses are due to obsolescence. Any method of calculating depreciation expense is subject to inaccuracy. No one can estimate exactly the length of life of a machine or its available stock of services. The development of new technology in machines has a different effect in altering machine values for different farm operators. New technical improvements may make an item of agricultural equipment obsolete for one farmer, but another might not consider the machine as being obsolete. Also the annual use of a machine might be so high that it is worn out in a relatively short time. Considering that a machine has a certain stock of services when purchased, high annual use will deplete these services in a short time. The machine might be of little value because of the large percentage of services already used, yet its loss of value through time and obsolescence is insignificant.

Depreciation charges may be calculated on three valuation bases: original, reproduction, or replacement costs.

Original cost is used most widely as a valuation base because of its simplicity. However, with the market price fluctuations of recent years, considerable support has been generated for the use of reproduction cost (the cost of the machine today). To allow for future price changes the replacement cost is used as the base.

Several difficulties arise in using the reproduction and replacement costs. The replacement method assumes that future prices can be predicted.

The reproduction method assumes that a satisfactory index is available for calculating present prices of all machines.[4]

Original 1954 purchase prices, obtained from dealers, were used as a basis for calculating depreciation costs. These current costs for new machinery were used instead of either reproduction or replacement costs to simplify the actual calculations. Use of reproduction costs would not alter the results substantially from those found with the current purchase price and the use of replacement costs, with the necessity of predicting future replacement costs, might not give a more relevant figure.

Since depreciation costs are due to both obsolescence and actual use, it is economically preferable to use a method of calculation which takes both of these factors into account. Such a method would fix obsolescence depreciation at some constant amount per year, whether or not a machine is used. On the other hand depreciation associated with use would vary as use varies.[5]

Basically, fixed depreciation costs are due to obsolescence or time. Any item of equipment has an estimated life with respect to time. At the end of this estimated life, the machine should be valueless because of obsolescence. As a result, the depreciation cost subject to time can be determined by dividing the original cost by the estimated length of life.

4/ R. G. Murphy and R. C. Suter, Methods of Calculating Depreciation of Farm Machinery, A. E. 729, Cornell University Agricultural Experiment Station, April, 1950, p. 6.

5/ Orlin J. Scoville, Fixed and Variable Machine Depreciation, Agricultural Economics Research, July, 1949, pp. 10-15.

This gives a depreciation expense which is equally allocated over the estimated years of life.

Variable depreciation costs are due to the amount of use. The basis for calculating the variable depreciation costs is the amount of use or services in terms of acres or hours purchased with the machine. The depreciation cost subject to use is the original cost divided by the total services in acres or hours. This gives the cost per unit of use. When this figure is multiplied by the number of units of use (hours or acres), the annual cost of depreciation is obtained.

The final depreciation cost and how it is obtained can be illustrated more fully by the use of the following diagram. (Figure 12)

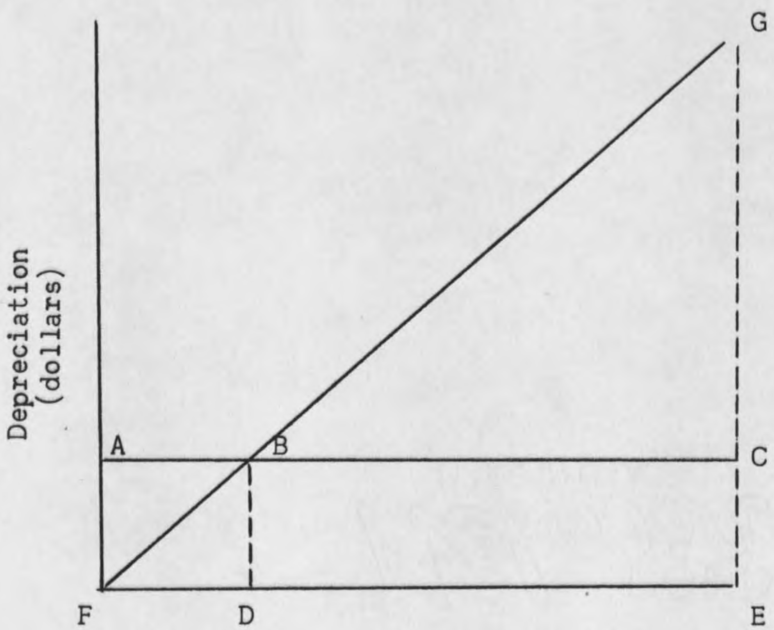

Figure 12. Fixed and Variable Depreciation

Line AC indicates the depreciation costs based on time and obsolescence with an annual depreciation cost of AF. This cost is the same in any given year during the estimated life of the machine provided it remains idle or is used a very limited amount. FE is the amount of services in hours purchased with the machine and FG gives the amount of depreciation costs commensurate with different amounts of use. In determining depreciation costs, either the cost due to obsolescence or the cost due to wear is used, depending on which is higher in a given year. If a machine is utilized FD amount of hours or less, the depreciation is AF dollars. When the annual use is larger than FD, the depreciation cost is determined according to the amount of use.

In calculating the depreciation costs (Table VII) several simple formulas are used which will more clearly illustrate the method used.

In calculating depreciation costs for tractors, the following formulas were used:

$$\text{Annual depreciation due to obsolescence} = \frac{\text{original cost} - \text{scrap value}}{\text{estimated life in years}}$$

$$\text{Depreciation cost per unit of use} = \frac{\text{original cost} - \text{scrap value}}{\text{estimated life in hours of use}}$$

Primary data indicate that the average scrap value of tractors was forty dollars. This figure was used in computing the depreciation costs for tractors. This scrap value is based upon the price paid for scrap metal, but cases may exist where individuals can obtain more for a completely worn out tractor. If this is the case, these special instances should be taken into consideration when computing depreciation costs.

TABLE VII. DEPRECIATION COSTS DUE TO TIME AND USE.

Item	Size	Annual Depreciation Costs due to Obsolescence	Depreciation Costs per Unit of use (A. & Hrs.)	Hrs. & A. of which use is an Effective Determinant
Tractor	4-plow (gas)	$234.00	.29 per/hour	807 hours
Tractor	4-plow (diesel)	298.00	.366	814 "
Tractor	5-plow (gas)	285.00	.35	814 "
Tractor	5-plow (diesel)	371.00	.45	824 "
Drill	10 foot	76.10	.22 per/acre	346 acres
Drill	12 foot	91.40	.16	571 "
Oneway	8 foot	107.42	.22	488 "
Oneway	10 foot	110.42	.19	581 "
Duckfoot	12 foot	38.30	.045	851 "
Duckfoot	14 foot	46.10	.046	1,002 "
Rodweeder	12 foot	28.53	.062	412 "
Combine (self-prop.)	12 foot	407.83	1.09	374 "
Combine (self-prop.)	14 foot	450.66	1.08	417 "
Combine (self-prop.)	16 foot	510.25	1.11	460 "

In calculating depreciation costs for combines, the scrap value was increased. It was assumed that combines do not depreciate to zero value. A scrap value of $150[6] was used in calculating depreciation.

Computational formulas are as follows:

$$\text{Annual depreciation due to obsolescence} = \frac{\text{original cost} - \$150}{\text{estimated life in years}}$$

$$\text{Depreciation cost per unit of use} = \frac{\text{original cost} - \$150}{\text{estimated life in acres of use}}$$

In the calculations for other items of equipment, scrap value was not considered because of the lack of accurate information as to what these

6/ Roy E. Huffman, Production Costs on Selected Dryland Grain Farms, Montana Agr. Exp. Station, Circular 52, Sept., 1949, p. 4.

values may be. The depreciation costs for the other implements were computed with the following formulas:

$$\text{Annual depreciation due to obsolescence} = \frac{\text{original cost}}{\text{estimated life in years}}$$

$$\text{Depreciation cost per unit of use} = \frac{\text{original cost}}{\text{estimated life in acres of use}}$$

Hours were used in calculating depreciation costs pertaining to tractors because the acres covered varies with different implements. If the size of implements are related to the power units to efficiently use the available power, machines with large power requirements may not cover a large number of acres but still cause the same wear and tear on the tractor.

Wear in other implements can be considered as uniform with each acre of use. Each implement performs a field operation over and over in approximately the same manner, thereby, producing little variability in wear between each acre of use.

THE ALTERNATIVES IN POWER AND MACHINERY

Suitable Machinery Combinations:

The machinery combinations used in this study comprise the most widely used sizes and types suitable for use with a given sized tractor. The types of machinery used are the modal types determined from empirical data which are the most widely used in performing the usual field operations.

To simplify this study, tractor sizes are restricted to those in most common use and the associated field equipment are restricted to an absolute minimum necessary to perform the required field operations. The essential equipment is indicated in Table VIII.

Sizes of field equipment used with the 4-plow and 5-plow tractors in performing the planting and tillage operations are those recommended by implement dealers for dryland conditions. (See Table VIII). The duckfoot and drill are pulled in tandem in the planting operation. The oneway is used for the first summerfallow operation and the duckfoot cultivator for each remaining fallow operation. A duckfoot which is wider than the drill was used in the machinery combination to more fully utilize the available tractor power. The width of the duckfoot is reduced by the removal of shovels when used in conjunction with a drill during the seeding operation. When used alone in the summerfallowing operation, the duckfoot is used at its full width.

TABLE VIII. REQUIRED MACHINERY ASSOCIATED WITH 4-PLOW AND 5-PLOW TRACTORS FOR USE ON MONTANA DRYLAND SPRING WHEAT FARMS.

4-Plow Combinations	5-Plow Combinations
4-Plow Tractor	5-Plow Tractor
8' Oneway	10' Oneway
10' Drill	12' Drill
12' Duckfoot	14' Duckfoot

Timeliness of Operation

For each size of farm, a time schedule was set up to show the daily capacity, for each implement or combination of implements, the days required to perform each field operation, and the annual acreage covered in each operation.

The capacity of each size of implement used is an average taken from the estimated performance rates given by the sample of farmers used in this study. Performance rates are computed on the basis of average acres per hour. Assuming a ten-day operation, the daily rate is ten times the hourly rate.

TABLE IX. AVERAGE RATES PER HOUR OF TILLAGE IMPLEMENTS.

Implement	Size	Ave. Acres Per/hr.
Oneway	8'	2.9
Oneway	10'	3.8
Drill & Duckfoot	10'	3.2
Duckfoot	12'	4.2
Duckfoot	12'	4.7
Duckfoot	14'	5.6

The average acres per hour of the various tillage implements are an average rate of performance when used with the recommended size of tractor (Table IX).

Assuming a ten-hour day of operation and a crop rotation which is half wheat and half fallow, the following (Tables X, XI, and XII) indicate how the two sizes of machinery combinations meet timeliness limits with respect to different sizes of farms. On the 944 acre farm, the 4-plow combination just fails to meet the timeliness criteria for the second and third duckfoot operations. The coverage of the required fallow acreage by the 4-plow tractor and the 12-foot duckfoot fails to meet the time requirements by three hours. Although the summerfallow operation is not considered as critical as the planting and harvesting operations in the reduction of yields, it does pose as a limiting factor in respect to timeliness of operation. At this time a decision is required to determine whether the inability to perform a field operation within certain time limits is important enough to substitute a larger machine or change the method of a field operation which would require another type of tillage implement, preferably one with a larger daily capacity and the same or lower per acre costs.

TABLE X. TIME SCHEDULE FOR 550 ACRE FARM, SHOWING DAILY CAPACITY FOR THE DISTINCT FIELD OPERATIONS, THE DAYS REQUIRED, AND ACRES COVERED.

Optimum Time Allowance and Operation	4-Plow Combination			5-Plow Combination		
	Acres per day	Number of days	Acres Covered Annually	Acres per day	Number of days	Acres Covered Annually
Planting (15-18 days)	32	8.6	275	42	6.6	275
1st Summerfallowing (20-25 days)	29	9.5	275	38	7.3	275
2nd Summerfallowing (10 days)	47	5.8	275	56	4.9	275
3rd Summerfallowing (10 days)	47	5.8	275	56	4.9	275
Total days		29.7			23.7	
Total hours		297			237	

TABLE XI. TIME SCHEDULE FOR 944 ACRE FARM, SHOWING DAILY CAPACITY FOR THE DISTINCT FIELD OPERATIONS, THE DAYS REQUIRED, AND ACRES COVERED.

Optimum Time Allowance and Operation	4-Plow Combination			5-Plow Combination		
	Acres per day	Number of days	Acres Covered Annually	Acres per day	Number of days	Acres Covered Annually
Planting (15-18 days)	32	14.8	472	42	11.3	472
1st Summerfallowing (20-25 days)	29	16.2	472	38	12.4	472
2nd Summerfallowing (10 days)	47	10.3	472	56	8.5	472
3rd Summerfallowing (10 days)	47	10.3	472	56	8.5	472
Total days		51.6			40.7	
Total hours		516			407	

Since one machinery combination would not meet the timeliness of operation requirements, it became necessary to use two combinations of equipment on the large farm. Two 5-plow combinations were used. It was evident that 4-plow combinations would not be adequate to perform field operations within designated time spans. If the 2,344 acres are

TABLE XII. TIME SCHEDULE FOR 2,344 ACRE FARM, SHOWING DAILY CAPACITY FOR THE DISTINCT FIELD OPERATIONS, THE DAYS REQUIRED, AND ACRES COVERED.

Optimum Time Allowance and Operation	Two 5-Plow Combination			One 5-Plow Combination		
	Acres per day	Number of days	Acres Covered Annually	Acres per day	Number of days	Acres Covered Annually
Planting (15-18 days)	84	13.9	1,172	42	13.9	586
1st Summerfallowing (20-25 days)	76	15.4	1,172	38	15.4	586
2nd Summerfallowing (10 days)	112	10.4	1,172	56	10.4	586
3rd Summerfallowing (10 days)	112	10.4	1,172	56	10.4	586
Total days		50			50	
Toal hours		500 (1,000 man hours)			500	

divided into halves the number of acres are indicated which need to be covered in each summerfallow and planting operation. It is quickly evident that the 1,172 acre coverage required for each field operation is an impossible task for one combination. Furthermore, two 4-plow combinations used simultaneously on 1,172 acres will not cover the required acres as quickly as necessary. The 944 acre farm illustrated that the 4-plow combination did not meet timeliness of operation criteria when only a 472 acre coverage was required for each field operation. On the larger farm, each combination must cover 586 acres per field operation. As a result, the 4-plow combination was considered as inadequate and it was not considered as an alternative on the 2,344 acre farm.

At the 586 acre level, as indicated by Table XII, the second and third summerfallow operation become the limiting operations for the 5-plow combination. At this acreage level these field operations require four hours more than the allocated time to perform the summerfallow operation. The 1,172 acre dryland crop farm or something slightly smaller establishes the upper limit with respect to acres of cropland where the 5-plow combination could be used and still remain within timeliness of operation limits.

Gasoline Tractors With Given Machinery:

As the previously presented material indicates, machinery combinations must fit certain timeliness of operation criteria. But within these criteria, alternatives exist in terms of size and type of machines. The relationships between fixed and variable costs, associated with variations in the amount of use, are analyzed to determine when a shift should take place in the size of implements or the size of machinery combinations.

In comparing the machinery combinations wholly in terms of cost per acre of cropland, the timeliness of operation limits loses a great deal of significance. It becomes apparent that a lower cost per acre of operating the 5-plow combination relative to the 4-plow combination is attained before the 4-plow combination reaches its time limits of operation. The results given in Figure 13 indicate that timeliness of operation is relatively unimportant in a choice between different sizes of machinery combinations. If the farm operator is not restricted by other factors, in

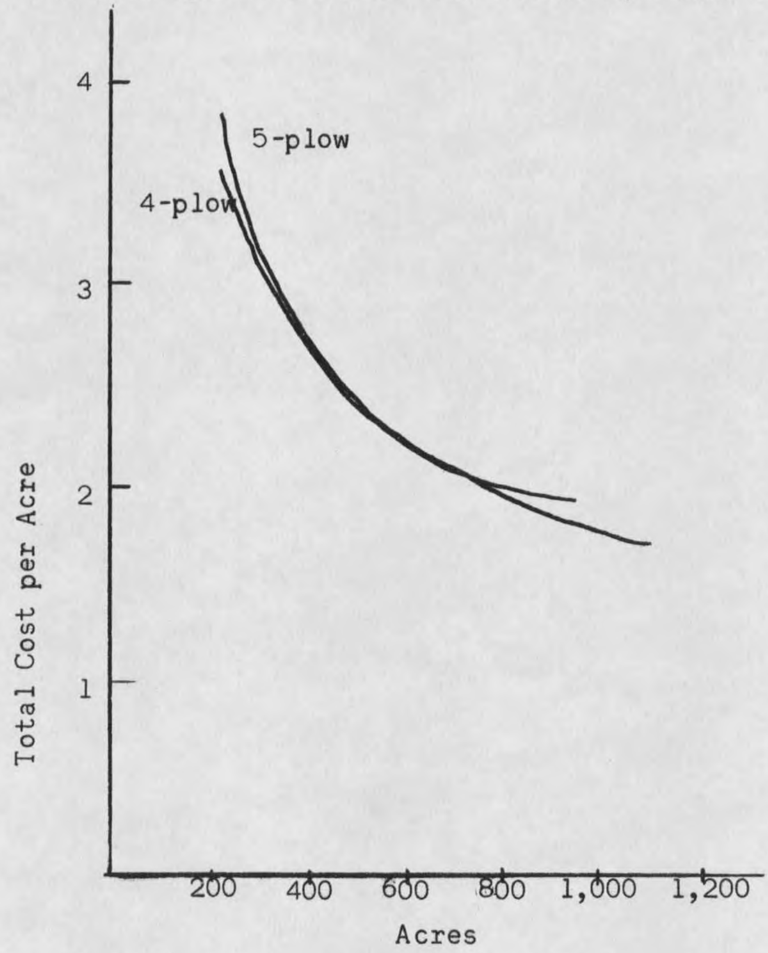

Figure 13. Total Cost per Acre of 4-Plow and 5-Plow Machinery Combinations Within Range of Timeliness of Operation.

preventing a shift, it would be beneficial from the standpoint of minimizing costs to shift to a larger combination. The 4-plow combination will meet the timeliness of operation limits on a dryland wheat farm with as much as 940 crop acres. However, the total cost per acre is less with the 5-plow combination than with the 4-plow combination when the size of the farm reaches approximately 700 acres.

Costs for the Small Farm

In determining what the optimum combination would be for the 550 acre farm, the difference in the cost per acre was the final criterion, within the time limits specified for the various operations. As both combinations easily met the timeliness of operation requirements neither combination was ruled out upon these grounds. It was necessary to base the decision on the relationships of fixed and variable costs associated with the two sizes of machinery combinations. These costs, brought about by a designated amount of use on a given acreage, determined which combination would have the lower total cost per acre.

Table XIII indicates the magnitude of the fixed and variable costs associated with the machinery combination in performing the required field operations. Depreciation, interest on investment, taxes, and insurance costs along with the variable costs associated with machinery combinations using gasoline power are shown for the 550 acre farm.

On an average total cost per acre basis, the 4-plow combination is four cents cheaper to own and operate. The difference in total cost between the two sizes of machinery combinations is not likely to be significant. A choice between the two sizes would probably take place on some other grounds.

The total fixed costs per acre of the 4-plow combination are $1.20 in comparison to $1.43 for the 5-plow combination. Variable costs for the 4-plow combination are $1.15 per acre while the 5-plow combination has an average variable cost of $ .97.

TABLE XIII. COSTS OF OPERATING 4-PLOW AND 5-PLOW MACHINERY COMBINATIONS USING GASOLINE POWER ON THE 550 ACRE FARM.

Machine Item	Total Annual Use	Depre-ciation	Interest, Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
(4-Plow Combination)						
Tractor (gasoline 4-plow)	297 hrs.	$234.00	$123.28	Planting	275	$182.87
10' Drill	275 A.	76.10	30.48	Onewaying	275	186.72
12' Duckfoot	825 A.	38.30	22.96	Duckfooting	550	261.25
8' Oneway	275 A.	107.40	30.08			
Totals		$455.80	$206.80	Tot. Var. Costs		$630.84
Total Fixed Costs			$662.60			
Total Costs						$1,293.44
Average Total Cost per Acre						$2.35
(5-Plow Combination)						
Tractor (gasoline 5-plow)	237 hrs.	$285.00	$149.76	Planting	275	$161.15
12' Drill	275 A.	91.40	32.96	Onewaying	275	157.57
14' Duckfoot	825 A.	46.10	27.68	Duckfooting	550	214.50
10' Oneway	275 A.	119.40	33.44			
Totals		$541.90	$243.84	Tot. Var. Costs		$533.22
Total Fixed Costs			$785.74			
Total Costs						$1,318.96
Average Total Cost per Acre						$2.39

Substituting Capital for Labor

The choice between the two machinery combinations may very well be made on the availability of labor and capital. If the supply of labor were critical or the price of labor were high, sixty hours of labor could be saved by using the 5-plow combination. If the amount of capital is limited the farm operator can substitute the use of labor for capital in performing the various farm operations.

On the 550 acre farm where choices of machinery are between a 4-plow combination and the 5-plow combination and the charge for labor is one dollar per hour, it is advantageous to substitute labor for machine services.

In substituting a 5-plow machinery combination for a 4-plow machinery combination on a 550 acre farm, what must the price of labor be before a shift will minimize costs?

The cost of machine services for the 4-plow combination (total machine costs less labor costs) is $996.16, while the cost of machine services for the 5-plow combination is $1,081.54 (Table XIV). The 4-plow combination

TABLE XIV. COSTS RELATED TO 4-PLOW AND 5-PLOW MACHINERY COMBINATIONS USING GASOLINE TRACTORS LESS LABOR COSTS ON THE 550 ACRE FARM.

Type of Costs	4-Plow	5-Plow
Depreciation, interest, taxes, and insurance	$662.60	$785.74
Variable costs less labor costs associated with:		
Planting	97.07	94.05
Onewaying	91.84	82.25
Duckfooting	144.65	116.50
Totals	$996.16	$1,081.54

reduces costs of machine services by $85.38 in relation to a six day (60 hour) reduction in the amount of labor by using the 5-plow combination (see Table X). As a result, one hour of labor substitutes for $1.42 of machine services and the price of labor must be higher than $1.42 per hour before costs are minimized by substituting the 5-plow combination for the 4-plow combination.

However, this analysis is readily applicable only to cases where labor is hired. In instances where labor is provided by the family no out-of-pocket expenses are involved and no set rate can be placed on family labor. Instead of considering family labor at any specific rate its cost is the opportunity costs to the operator and his family in some other job.

Costs for the Medium Farms

Using the same type of analysis, the total, fixed, and variable cost relationships can be determined for the 944 acre farm. In analyzing the two sizes of machinery combinations, the same type of field operations are used and the variable costs per acre are identical to those of the 550 acre farms. Except for the larger size of farm, all conditions remain the same as those found on the smaller farm.

When the 4-plow and 5-plow machinery combinations are used on the 944 acre farm, the 5-plow combination is the least costly to own and operate. Total per acre costs associated with owning and operating the 4-plow combination are $1.91 per acre. The average total costs of the 5-plow combination are $1.82 per acre (Table XV).

The total fixed costs per acre of the 4-plow combination are $ .76, compared with $ .85 for the 5-plow combination. Variable costs of the 4-plow combination are $1.15 per acre. The 5-plow combination has a variable cost of $ .97 per acre.

On the 944 acre farm, the substitution of capital for labor definitely reduces the costs associated with power equipment and machine use. The use of the 5-plow combination would entail a saving of 9 cents per acre of cropland over the cost of using the 4-plow combination.

TABLE XV. COSTS OF OPERATING 4-PLOW AND 5-PLOW MACHINERY COMBINATION WITH GASOLINE POWER ON 944 ACRE FARM.

Machine Item	Total Annual Use	Depre- ciation	Interest, Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
(4-Plow Combination)						
Tractor (gasoline 4-plow)	516 hrs.	$234.00	$123.28	Planting	472	$313.88
10' Drill	472 A.	76.10	30.48	Onewaying	472	320.49
12' Duckfoot	1416 A.	38.30	22.96	Duckfooting	944	448.40
8' Oneway	472 A.	107.40	30.08	Var. depr. costs		53.15
Totals		$455.80	$206.80	Tot. Var. Costs		$1,135.92
Total Fixed Costs			$662.60			
Total Costs						$1,798.52
Average Total Cost per Acre						$1.91
(5-Plow Combination)						
Tractor (gasoline 5-plow)	407 hrs.	$285.00	$149.76	Planting	472	$276.59
12' Drill	472 A.	91.40	32.96	Onewaying	472	270.46
14' Duckfoot	1416 A.	46.10	27.68	Duckfooting	944	368.16
10' Oneway	472 A.	119.40	33.44	Var. depr. costs		19.04
Totals		$541.90	$243.84	Tot. Var. Costs		$934.25
Total Fixed Costs			$785.74			
Total Costs						$1,719.99
Average Total Cost per Acre						$1.82

The total cost of the machine services for the 4-plow combination, less labor costs, is $1,288.30. The cost of machine services for the 5-plow combination, less labor costs, is $1,311.69 (Table XVI). The 4-plow combination reduces the costs of machine services by $23.39, while the use of the 5-plow combination reduces the amount of labor by 109 hours (Table XI).

As a result, $ .22 of machine services substitute for one hour of labor. With this type of relationship, the cost of labor must be less than $ .22 per hour. Until the price of labor becomes this low, costs will not be minimized by substituting labor for machine services in the farming operation.

TABLE XVI. COSTS RELATED TO 4-PLOW AND 5-PLOW MACHINERY COMBINATIONS USING GASOLINE TRACTORS LESS LABOR COSTS ON THE 944 ACRE FARM.

Type of Costs	4-Plow	5-Plow
Depreciation, interest, taxes, and insurance	$ 715.76	$ 804.77
Variable costs less labor costs associated with:		
Planting	166.62	161.42
Onewaying	157.65	146.32
Duckfooting	248.27	199.18
Totals	$1,288.30	$1,311.69

Rodweeder Alternative

Assuming that soil conditions are favorable, use of a rodweeder presents an important alternative in machine use. Due to its light draft, costs and running time are reduced. The faster performance rate and light draft reduce the variable operating costs, making it possible to reduce the total costs per acre of tillage operations.

The medium size farm can be used as an illustration of how time limits for operations can be met by the introduction of another implement in the machinery combination. The use of a 4-plow machinery combination failed to meet the time limits of operation in the second and third summer-fallow operation. The duckfoot did not have the necessary capacity to till the required acres in ten days. Substitution of a rodweeder in the machinery combination decreased the time required to perform each summerfallow operation by one day. Where the duckfoot required 10.3 days to cultivate 472 acres, the rodweeder accomplished the task in 9.25 days.

Table XVII shows the per acre cost of summerfallowing by using the duckfoot or rodweeder. The $ .66 per acre cost of rodweeding is considerably less than the $ .72 per acre cost of duckfooting fallow.

TABLE XVII. AN ANALYSIS OF COSTS PER ACRE OF RODWEEDING AND DUCKFOOTING OPERATIONS ON THE 944 ACRE FARM.

Costs	Rodweeding	Duckfooting
Tractor		
Depreciation/acre	$ .12	$ .12
Interest/acre	.065	.065
Machinery		
Depreciation/acre	.062	.04
Interest/acre	.02	.024
Operating Costs		
Fuel/acre	.09	.112
Oil/acre	.01	.013
Machinery repair/acre	.048	.061
Tractor repair/acre	.051	.077
Labor/acre	.196	.212
Total Cost per Acre	$ .662	$ .724

However, this comparison is limited only to the second and third summerfallow operations. It does not take into consideration the fact that the fixed costs associated with machine use are increased by having both a duckfoot and a rodweeder in the machinery combination. In considering the total costs of owning and operating the machinery combination the inclusion of a rodweeder will reduce the variable operating costs of the second and third summerfallow operations, but total fixed costs will be increased for the entire combination.

Costs for the Large Farm

The 2,344 acre farm provides a final cost analysis of a machinery combination, using gasoline power, relative to a given acreage of cropland. On this size of farm, the 4-plow combination no longer meets the timeliness of operation limits. As a result, the 4-plow combination was ruled out as inadequate on the large farm and only the 5-plow combination is used in the cost analysis.

Two 5-plow combinations are used simultaneously to provide the large daily acreage capacity required to perform the various field operations within required time limits. One 5-plow combination was inadequate. Table XII indicates that even the two 5-plow combinations, used simultaneously, failed by a small margin to meet timeliness of operation limits in the second and third summerfallow operations.[7/]

Although the 5-plow combination was not compared with a machinery combination of another size, it did provide a basis for a more complete relationship of fixed and variable costs in respect to a greater amount of annual use. In addition, the timeliness of operation limits are established for the 5-plow combination.

To determine the cost of ownership and operation of one 5-plow combination on a 2,344 acre farm, it was necessary to divide the work load

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7/ In specific cases this pressure of timeliness of operation could possibly be eased by the use of diesel power.

equally between the two machinery combinations. This means that one 5-plow combination must provide one half of the machine services in each field operation. Each machinery combination must provide the power and machinery requirements for planting one half (586 acres) of the 1,172 acres planted each spring. The 1,172 acres covered in each summerfallow operation is divided in a similar manner.

The costs shown in Table XVIII are determined on the basis of two 5-plow combinations performing the field operations simultaneously on 2,344 acres of cropland. Half of the field operations are performed by one 5-plow combination which would be equivalent to one machinery combination

TABLE XVIII. COST OF OPERATING ONE 5-PLOW COMBINATION ON A 2,344 ACRE FARM.

Machine Item	Total Annual Use	Depre-ciation	Interest Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
Tractor (gasoline 5-plow)	500 hrs.	$285.00	$149.76	Planting	586	$ 343.40
12' Drill	586 A.	91.40	32.96	Onewaying	586	335.78
14' Duckfoot	1758 A.	46.10	27.68	Duckfooting	1172	454.74
10' Oneway	586 A.	110.42	33.44	Var. depr. costs		37.97
Totals		$532.92	$243.84	Total var. costs		$1,171.89
Total Fixed Costs			$776.76			
Total Costs						$1,948.65
Average Total Cost per Acre						$1.66

on a 1,172 acre farm. The cost figures shown in Table XVIII are those for one machinery combination. To obtain the total machine costs for the 2,344 acre farm, the figures should be doubled.

The average total cost per acre of a 5-plow combination, used on 1,172 acres, is $1.66. Average fixed costs are $ .66 per acre; the average variable costs are $1.00 per acre.

Most Profitable Gasoline Combination

The cost relationships obtained from varying the acreage with respect to a given size of machinery combination substantuates the following points which should be considered in determining what machine to buy: (1) the difference in the first cost of the large and small machines, (2) the annual use to be made of the machine, (3) the amount of labor saved by the large machine, and (4) the relative values of capital and on the farm.8/

Differences in first costs are significant. A higher first cost means a higher fixed cost. If the difference in the first cost of the larger machine is a great deal more than the first cost of the smaller machine, the higher fixed costs of the larger machine will not be offset by the labor and other variable costs saved in using the larger machine.

This same comparison is used in comparing the 4-plow and 5-plow machinery combination. The original cost of the 5-plow combination was $6,095, while the cost of the 4-plow combination was $5,243. The effect these first costs had on fixed costs is illustrated in Figure 14. The average fixed costs per acre for the 5-plow combination used on 550 acres of cropland are $1.43 per acre, while the average fixed costs for the 4-plow combination are $1.20 per acre.

As the annual use of the machinery combinations increases, the higher total fixed costs of the larger machinery combination are spread over more and more units of use in terms of acres and the differences between the average total fixed costs per acre of the larger machine and the smaller machine decreases. Figure 14 illustrates the convergence of the average total fixed cost curves of the 4-plow and 5-plow machinery combinations.

8/ Heady and Jensen, op. cit., p. 379.

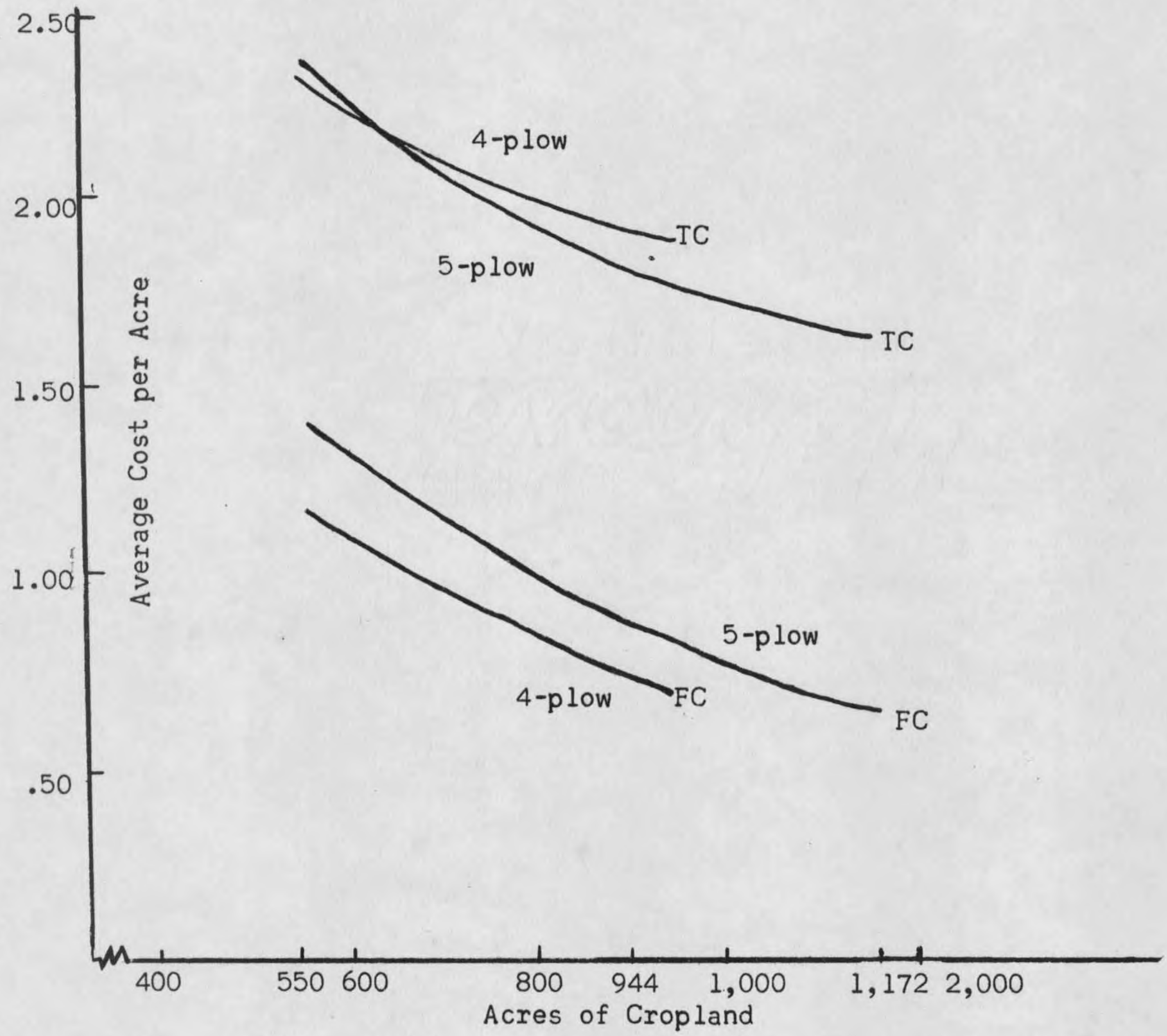

Figure 14. Average Total and Fixed Costs per Acre for 4-Plow and 5-Plow Machinery Combination

The amount of annual use is an important determinant of the profitability of a small or large machine. In Figure 14 the average total cost curves indicate the effect of annual use relative to the 4-plow and 5-plow machinery combinations. At approximately 600 acres the average total cost per acre of the 5-plow combination becomes less than the average total cost of the 4-plow combination.

As the average variable costs per acre remains the same with increased use (variable depreciation costs excluded), the decline in average total costs per acre is due to the decline in average fixed costs per acre relative to increased annual use. However, the increase in variable depreciation costs (Table XIX) per acre are more than offset by the decrease in fixed costs.

TABLE XIX. AVERAGE VARIABLE DEPRECIATION COST PER ACRE WITHIN RANGE OF TIMELINESS OF OPERATION.

Size of Machinery Combination	Acres of Cropland		
	500	944	1,167
4-plow	0	$.056	
5-plow	0	.02	$.032

Diesel Tractors and Given Machinery:

The utilization of diesel power in the farming operation is another alternative available to the dryland farmer. Diesel power affects tractor costs in two ways: (1) it reduces the variable costs and (2) increases the fixed costs. Variable costs are reduced by the utilization of a lower-priced fuel, while fixed costs increase because of a higher original cost.

Profitability of using diesel tractors depends upon the extent that reduced fuel costs will offset the added fixed costs. If a rise in the cost of the diesel tractor increases the fixed costs by a large amount, it may be impossible for the reduced fuel costs to offset these higher fixed costs.

Hence, gasoline tractors provide a more economical source of power on small acreages. As the annual use of tractors is increased the higher total fixed costs on the diesel tractor are spread over more and more units of service and the differences in costs between the gasoline and diesel power units are lessened.

To determine the advantages or disadvantages of using diesel power, diesel tractors of the same size are substituted in the machinery combinations in place of gasoline tractors. The performance rates for various field operations are assumed identical to those of the gasoline tractor. All equipment used with the diesel tractor are the same as those used with gasoline tractors of the same size. Each size of farm is taken individually and the 4-plow and 5-plow diesel tractor with its given machinery are related to the given acreage.

Timeliness of operation limits are used in the same manner in analyzing diesel power, as they were used with respect to gasoline power. The 4-plow combination is not considered on the large farm because of limits in timeliness of operation and 944 acres of cropland established the timeliness of operation limit for the 4-plow machinery combination.

In determining how the use of diesel power compares with gasoline power, the two sizes of diesel tractors with a given complement of field equipment is analyzed first on the 550 acre farm. The total, fixed, and variable costs are determined for each size of power equipment and machinery combination.

Costs for the Small Farm

Table XX indicates the magnitude of the total, fixed, and variable costs of the 4-plow and 5-plow machinery combinations in performing the required field operations on a 550 acre farm.

TABLE XX. COSTS OF OPERATING 4-PLOW AND 5-PLOW MACHINERY COMBINATIONS WITH DIESEL TRACTORS ON THE 550 ACRE FARM.

Machine Item	Total Annual Use	Depreciation	Interest, Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
(4-Plow Combination)						
Tractor (diesel 4-plow)	297 hrs.	$298.00	$157.84	Planting	275	$169.68
10' drill	275 A.	76.10	30.48	Onewaying	275	176.00
12' duckfoot	825 A.	38.30	22.96	Duckfooting	550	244.20
8' oneway	275 A.	107.40	30.08			
Totals		$519.80	$241.36	Total Variable Costs		$589.88
Total Fixed Costs			761.16			
Total Costs						$1,351.04
Average Total Cost per Acre						2.45
(5-Plow Combination)						
Tractor (diesel 5-plow)	237 hrs.	$371.00	$192.72	Planting	275	$139.98
12' drill	275 A.	91.40	32.96	Onewaying	275	139.98
14' duckfoot	825 A.	46.10	27.68	Duckfooting	550	213.40
10' oneway	275 A.	119.40	33.44	Total Variable		
Totals		$627.90	$286.80	Costs		$493.36
Total Fixed Costs			$914.70			
Total Costs						$1,408.06
Average Total Cost per Acre						2.56

In comparing the average total costs per acre the 4-plow machinery combination using diesel power is more economical to own and operate than the 5-plow combination. The average total cost per acre for the 4-plow combination is $2.45, while the average total costs per acre of the 5-plow combination are $2.56. Average total fixed costs for the 4-plow combination are $1.38 in comparison to $1.66 for the 5-plow combination. Average total variable costs are $1.07 for the 4-plow combination while the average total variable costs for the 5-plow combination are $.90.

The use of the 4-plow combination decreases per acre costs by eleven cents and a choice between the two sizes of combinations would favor the larger combination. The higher fixed costs involved in the use of the larger combination are offset by the decrease in variable costs.

In the previous comparison of machinery combinations using gasoline power on the 550 acre farm the 4-plow combination was judged the most economical to own and operate. The average total cost per acre of $2.35 was less than the average total cost of the 5-plow combination. On this basis of determining the optimum machinery combination, how does the 4-plow gasoline combination compare with the 4-plow diesel combination on the 550 acre farm?

In comparing the average total cost per acre the $2.45 cost per acre of the 4-plow diesel is 10 cents more per acre than the 4-plow gasoline combination. The spread of the per acre costs of two combinations gives the 4-plow gasoline combination only a slight profit advantages.

Costs for the Medium Farms

A similar comparison is possible on the 944 acre farm. The 4-plow and 5-plow machinery combinations using diesel power are compared on the larger acreage to determine the various cost relationships and the most profitable combination of power equipment and machinery.

When the 4-plow and 5-plow diesel combinations are used on the 944 acre farm on the 5-plow combination is the most profitable to own and operate. Total costs per acre associated with owning and operating the 4-plow combination are $1.94. The average total costs per acre of the 5-plow combination are $1.87 (Table XXI).

TABLE XXI. COSTS OF OPERATING 4-PLOW AND 5-PLOW MACHINERY COMBINATIONS WITH DIESEL TRACTORS ON 944 ACRE FARMS.

Machine Item	Total Annual Use	Depreciation	Interest, Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
(4-Plow Combination)						
Tractor (diesel 4-plow)	516 hrs.	$298.00	$157.84	Planting	472	$291.22
10' Drill	472 A.	76.10	30.48	Onewaying	472	302.08
12' Duckfoot	1416 A.	38.30	22.96	Duckfooting	944	419.14
8' Oneway	472 A.	107.40	30.08	Var. depreciation		53.15
Totals		$519.80	$241.36	Total Variable Costs		$1,065.59
Total Fixed Costs			$761.16			
Total Costs						$1,826.75
Average Total Cost per Acre						$1.94
(5-Plow Combination)						
Tractor (diesel 5-plow)	407 hrs.	$371.00	$192.72	Planting	472	$240.25
12' Drill	472 A.	91.40	32.97	Onewaying	472	240.25
14' Duckfoot	1416 A.	46.10	27.68	Duckfooting	944	366.27
10' Oneway	472 A.	119.40	33.44	Var. depreciation		19.04
Totals		$627.90	$286.80	Total Variable Costs		$865.81
Total Fixed Costs			$914.70			
Total Costs						$1,780.51
Average Total Cost per Acre						$1.87

The total fixed costs per acre of the 4-plow combination are $ .81, compared with $ .97 for the 5-plow combination. Variable costs of the 4-plow combination are $1.12 per acre while the 5-plow combination has a variable cost of $ .92 per acre.

Costs for the Large Farms

On the 2,344 acre farm the 4-plow combination was not considered as an alternative. The analysis of gasoline tractors indicated the 4-plow combination did not meet timeliness of operation requirements on the 2,344 acre farm. Two 5-plow combinations are again used simultaneously on 2,344 acres of cropland to perform the field operations. Half of the field operations are performed by one 5-plow combination which is equivalent to one machinery combination being used on 1,172 acres. The 1,172 acres of cropland is the acreage base for testing the 5-plow diesel powered combination on the large farm.

The calculated total costs in Table XXII are determined on the basis of 1,172 acres of cropland. These costs, plus a similar amount from another 5-plow machinery combination, determine the total power equipment and machinery costs for the 2,344 acre farm.

TABLE XXII. COST OF OPERATING ONE 5-PLOW MACHINERY COMBINATION WITH DIESEL POWER UNIT ON A 2,344 ACRE FARM.

Machine Item	Total Annual Use	Depre-ciation	Interest, Taxes, & Insurance	Field Operation	Acres Covered	Variable Costs
Tractor (diesel 5-plow)	500 hrs.	$371.00	$192.72	Planting	586	$298.27
12' Drill	586 A.	91.40	32.96	Onewaying	586	298.27
14' Duckfoot	1758 A.	46.10	27.68	Duckfooting	1172	434.82
10' Oneway	586 A.	110.42	33.44	Var. depr. costs		37.97
Totals		$618.92	$286.80	Total Variable Costs		$1,069.35
Total Fixed Costs			$905.72			
Total Costs						$1,975.05
Average Total Cost per Acre						$1.68

The average total costs per acre of a 5-plow combination with diesel power used on 1,172 acres are $1.68. Average total fixed costs are $ .77 per acre and the average variable costs are $ .91 per acre.

Optimum Combination:

The fixed and variable cost relationships associated with the use of diesel power in the machinery combination are important in determining which size of machinery combination is the most profitable. The fixed cost relationships with respect to first costs of equipment and amount of annual use are especially significant.

Diesel tractors are characterized by high first costs and high fixed costs. The first costs of diesel tractors are considerably higher than gasoline tractors of similar horsepower. Table VI indicates that a 4-plow gasoline tractor can be purchased for $3,082 while the 4-plow diesel tractor has an initial cost of $3,874.

The magnitude of the increase in fixed costs resulting from the substitution of a diesel tractor for a gasoline tractor in a machinery combination is indicated by Figure 15. The fixed costs (depreciation, interest, on investment, taxes, and insurance) are higher, throughout the range of timeliness of operation, for the diesel tractor in relation to a gasoline tractor of similar size. This would indicate that the amount of annual use within timeliness limits is insufficient for the fixed costs of the diesel tractor to drop below those of a gasoline tractor.

When machinery combinations of the same size using gasoline and diesel power are compared, it becomes evident that the high fixed costs are not offset within the range of timeliness of operation by savings in lower fuel costs.[9] As Figure 15 illustrates, the total cost per acre of

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9/ Assuming the performance rates obtained from the use of diesel power are identical to those obtained from the use of gasoline power for a similar tractor.

the combinations using diesel power do not become less than the costs of combinations using gasoline power. The total cost per acre of the 4-plow diesel combination is always above the total cost per acre of the 4-plow gasoline combination, within the limits of timeliness of operation. Similarly the total costs of the 5-plow diesel combination remain greater than the total costs of 5-plow gasoline combination within the range of timeliness of operation.

Using total cost per acre as the basic criterion of choice, the total cost relationships in Figure 15 indicate the optimum machinery combinations relative to varying amounts of annual use. The total costs per acre indicated in Figure 15 show that the 4-plow gasoline combination is the most profitable to use until acres of cropland reach approximately 700 acres. Beyond 700 acres the 5-plow gasoline combination becomes the most profitable to own and operate. At no time within the acreage limitation imposed by timeliness of operation do the diesel powered combinations become the most economical combination of power equipment and machinery.

Within the range of acres of cropland, shown in Figure 15, the machinery combination with the lowest average total costs per acre is considered as the optimum combination. These cost relationships are limited to the acreage range imposed by time limits of operation. As the machinery combinations do not have sufficient capacity to perform field operations beyond this range of acres of cropland, costs associated with power equipment and machine use become irrelevant to the problem.

The lower terminals of the cost curves in Figure 15 indicate the timeliness of operation limits for a given size of machinery combination.

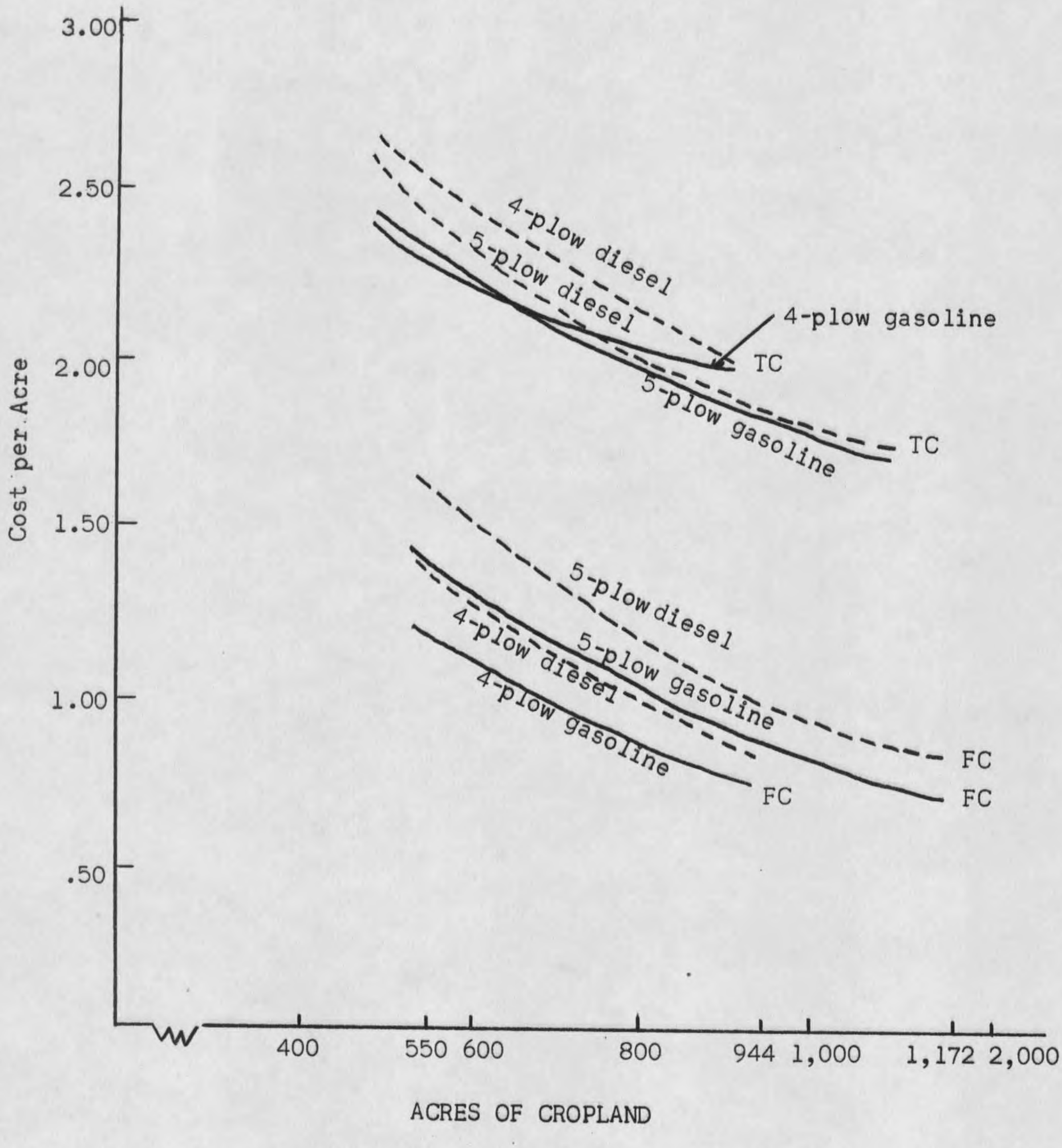

Figure 15. Average Total and Fixed Costs per Acre for 4-Plow and 5-Plow Machinery Combination Using Gasoline and Diesel Power.

The 4-plow combinations reached the limits with respect to timeliness of operation on 944 acres of cropland. The 5-plow combination no longer performed all of the field operations within set time limits at 1,172 acres.

These time limits served as the primary criteria in determining what size of machinery to use. Choices within the range of timeliness of operation are made on the lowest total cost per acre.

However, choices of optimum machinery combinations are limited to the discrete acreages of 550, 944, and 2,344. It is for these sizes of farms, used in this analysis that an optimum combination of power equipment and related field implements for planting and tillage are determined.

Summary of Combination Choices:

Beginning with the 550 acre farm the combination of equipment which will minimize costs and perform field operation within timeliness of operation limits is the 4-plow gasoline combination. As Table XIII shows the average total cost per acre of operating the 4-plow combination is $2.35 while the cost of owning and operating the next best alternative (5-plow gasoline combination) is $2.39 per acre.

On the 944 acre farm the 5-plow gasoline combination has the lowest per acre costs at $1.82 per acre, see Table XV, while the 5-plow diesel combination, which is the next best alternative has a per acre cost of $1.87. Finally, the most economical combination to use on the 2,344 acre farm is the 5-plow gasoline combination. The 5-plow gasoline combination has a total cost per acre of $1.66 compared to a total cost of $1.68 for the 5-plow diesel combination.

The foregoing figures illustrate that the total costs per acre between the optimum combination and the next best alternative for a given acreage are not large. The savings in actual dollars are small and a change in the price of such items as fuel, labor, and repair parts could affect the choice of an optimum machinery combination. If the costs of specific items such as labor or gasoline increase, the machinery combinations which use these high cost items in the greatest amount will be placed at a relative disadvantage comparable to combinations which do not use these items in such abundance.

The choice between the 4-plow gasoline combination and the 5-plow gasoline combination on the 550 acre farm could be affected by the cost of labor (see pages 59 and 60). If the supply of labor is limited, raising the cost of labor to $1.42 per hour, the 5-plow gasoline combination will become the most profitable to own and operate. When the price of labor becomes $1.42 per hour it is profitable to substitute capital for labor in the machinery combination.

The choices available in tractors and their related tillage and planting equipment on the 944 and 2,344 acre farms are between the 5-plow gasoline combination and the 5-plow diesel combination. In both cases the gasoline powered combination has lower costs per acre. The higher fixed costs due to the higher first costs of the diesel tractor are not offset by the reduction of variable costs. As Figure 15 illustrates, the 5-plow diesel combination reaches the limits of timeliness of operation before the costs associated with operation and ownership fall below those of the 5-plow gasoline combination.

Due to the narrow spread in total costs between the two machinery combinations, the final choice as to which type of power to use may hinge on the relative prices of gasoline and diesel fuel.

Figure 16 illustrates the break-even prices of gasoline and diesel fuel for 5-plow gasoline and 5-plow diesel combinations, used on a 2,344 acre farm. In performing the required field operations on this size of farm with diesel and gasoline power, one gallon of gasoline substitutes for .9 gallon of diesel fuel. Line OB in Figure 16 gives the rate of substitution of gasoline for diesel fuel. The X axis gives the price of gasoline, while the Y axis indicates the required break-even price of diesel fuel.

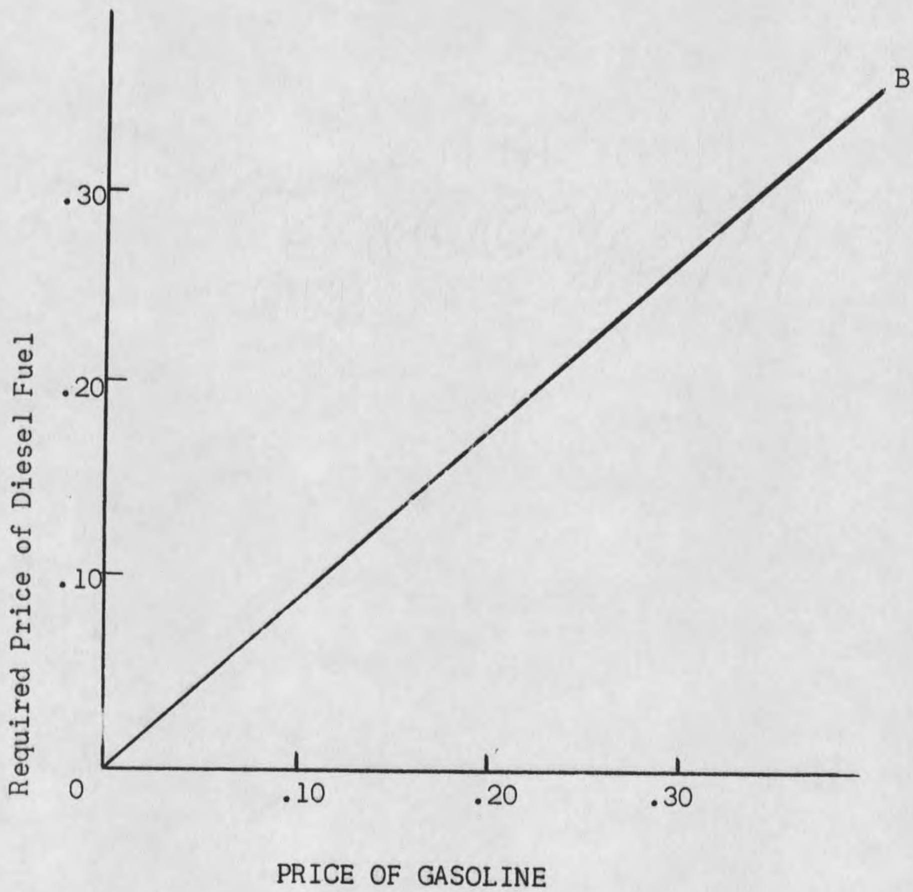

Figure 16. Break-even Prices of Gas and Diesel Fuel

The break-even price is the necessary purchase price for diesel fuel where diesel fuel can be substituted for gasoline and the cost of using diesel or gasoline power breaks even. If the price of diesel fuel is higher than the break-even price, gasoline will provide the most economical form of power. A price for diesel fuel lower than the break-even price will make diesel power the most economical.

In this study, gasoline power proved to be the most economical. However, individual cases are possible where the reverse situation could occur. The relative prices of diesel fuel and gasoline could change. An increase in the price of gasoline or a decrease in the price of diesel fuel[10] would affect the total cost per acre and bring about a shift to the use of diesel power. Situations are also possible where gasoline substitutes for diesel fuel in a different ratio. If the rate of substitution of diesel fuel for gasoline should become less than .9 gallons to one, a reduction in power costs which would be more favorable to the use of diesel power would occur.

Another one of the more important factors to consider in the selection of a diesel or gasoline power unit on a large acreage is the differences in performance provided by the two types of power in accomplishing the various farming operations. Hence, in considering the use of diesel power, the greater cost per acre may be offset by better performance in the various farming operations which in turn will increase the final yield. If the assumption is made that yields are increased by the better performance of diesel power, a choice of the type of power to use rests upon a comparison of the additional cost of owning and operating a diesel power unit and the additional returns through increased yields.

Under these conditions, the use of diesel power must increase yields to an extent where the additional cost of using this type of power is offset by the larger returns brought about by increased yields. If the

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10/ In this study the price of diesel fuel used is \$ .17 and the price of gasoline is \$ .22 per gallon.

increased returns do not offset increased costs, gasoline power would remain the most economical source of power to use.

Due to a lack of reliable information, this study does not attempt to evaluate the cost of using diesel or gasoline power relative to the respective yields obtained. However, if accurate information is available on the change in yields due to the use of a particular machinery combination, the increase in yields necessary to compensate for the increase in costs of using a particular combination can be calculated.

The following equations provide a method of determining which type of power to use with specific farm implements which will bring about the greatest return to net farm income. The equation $R_d = q_d\ P_w - C_d$ is used to determine the returns from the use of diesel power in a machinery combination and $R_g = Q_g\ P_w - C_g$ is used to determine the returns from the use of gasoline power in a similar machinery combination. R_d and R_g refer to the monetary returns of using either type of power in the machinery combination; Q_d and Q_g are the yields in bushels; P_w is the price of wheat or some other grain; and C_d and C_g are the costs associated with the use of each type of power unit.

Solving for $Q_d - Q_g$ by substituting in the equation

$$Q_d - Q_g = \frac{R_d - R_g + C_d - C_g}{P_w}$$

the amount of increase in yield necessary with the use of diesel power to obtain a break-even point can be determined. The increase in yield through the use of diesel power must be equal to or greater than this amount to make the use of diesel power the more advantageous to use.

Combines:

Harvesting represents one of the major jobs in dryland crop production and it is characterized by the use of expensive equipment. The high initial costs of self-propelled combines represent approximately one-half of total investment in farm equipment. Using 1954 prices, the purchase price of a 14 foot self-propelled combine was $5,558 compared to $5,170 to purchase the 4-plow gasoline combination required to perform the planting and tillage operations. In this example, the combine investment represented 51.8 percent of the total machinery investment.

Timeliness of Operation

To determine which size of combine would be the most profitable to own, the most widely used types and sizes of combines found in the sample area were tested on the 550, 944, and 2,344 acre farms. Survey data obtained from the sample area indicated that the most popular sizes of combines used are the 12-foot, 14-foot, and 16-foot self-propelled combines. As pull-type combines, found in use, are limited in numbers, the alternatives in the harvesting operation are limited to the 12-foot, 14-foot, and 16-foot sizes of self-propelled combines.

The three sizes of self-propelled combines are related to the given acreages to determine if each size could perform the harvesting operation within the time allowed. The harvesting operation must be completed within 15 days after the crop is ready for harvest, to prevent excessive losses in yields. Combines are considered adequate in size if harvesting is accomplished within 15 days.

Table XXIII indicates the acres per day that each size of combine can harvest and the number of days required to perform the harvesting operation on the 550, 944, and 2,344 acre farms. Each met the fifteen days time limit of operation on the three given sizes of farms.

TABLE XXIII. TIMELINESS OF OPERATION FOR SELF-PROPELLED COMBINES WITH A TIME LIMIT OF 15 DAYS ON THE 550, 944, AND 2,344 ACRE FARMS.

Size	550 Acre Farm			944 Acre Farm			(Two combines) 2,344 Acre Farm		
	Acres per Day	No. of Days	Acres Covered Annually	Acres per Day	No. of Days	Acres Covered Annually	Acres per Day	No. of Days	Acres Covered Annually
12'	39	7.05	275	39	12.1	472	39	15	586
14'	44	6.25	275	44	10.7	472	44	13.3	586
16'	48	5.7	275	48	9.8	472	48	12.2	586

The acreage on the 2,344 acre farm was so great that two combines were required to accomplish the harvesting operation. The number of acres to be harvested annually is 1,172. These acres were divided equally between the combines. As a result, each combine is required to harvest 586 acres during a given year.

Most Profitable Size

The most profitable size of combine to own and operate was determined by comparing the per acre costs of the combines when the combines are used on a given acreage. The tables that follow indicate the various costs for the 12', 14', and 16' combines on 550, 944, and 2,344 acre farms.

Comparison of the average total costs found in Tables XXIV, XXV, and XXVI, show that the 14' self-propelled combine minimizes costs on all three sizes of farms. The average total cost per acre of $3.34 for the 14' combine is four cents less than the total cost per acre of the 12' size on the 550 acre farm. The average total cost per acre is thirteen cents less than the 16' size on the 944 acre farm and twelve cents less than the 16' size on the 2,344 acre farm.

TABLE XXIV. FIXED, VARIABLE, AND TOTAL COSTS OF A TWELVE-FOOT SELF-PROPELLED COMBINE USED ON 550, 944, AND 2,344 ACRE FARMS.

	Size of Farm		
	550	944	2,344
Acres of Annual Use	275	472	586
Fixed depreciation	$407.83	$407.83	$407.83
Interest, taxes & insurance	201.76	201.76	201.76
Total fixed costs	609.59	609.59	609.59
Average fixed costs	2.22	1.29	1.04
Variable depreciation		106.82	228.90
Variable operating costs	324.22	556.49	688.54
Total variable costs	324.22	663.31	917.44
Average variable costs	1.18	1.40	1.57
Total costs	933.81	1,272.90	1,527.03
Average total costs	3.38	2.68	2.61

TABLE XXV. FIXED, VARIABLE, AND TOTAL COSTS OF A FOURTEEN-FOOT SELF-PROPELLED COMBINE USED ON 550, 944, AND 2,344 ACRE FARMS.

	Size of Farm		
	550	944	2,344
Acres of Annual Use	275	472	586
Fixed depreciation	$450.66	$450.66	$450.66
Interest, taxes & insurance	222.32	222.32	222.32
Total fixed costs	672.98	672.98	672.98
Average fixed costs	2.44	1.42	1.15
Variable depreciation		59.40	180.36
Variable operating costs	244.48	419.60	519.17
Total variable costs	244.48	479.00	699.53
Average variable costs	.88	1.02	1.20
Total costs	917.46	1,151.98	1,372.51
Average total costs	3.34	2.44	2.35

TABLE XXVI. FIXED, VARIABLE AND TOTAL COSTS OF A SIXTEEN-FOOT SELF-PROPELLED COMBINE USED ON 550, 944, AND 2,344 ACRE FARMS.

	Size of Farm		
	550	944	2,344
Acres of Annual Use	275	275	586
Fixed depreciation	$510.25	$510.25	$510.25
Interest, taxes & insurance	250.88	250.88	250.88
Total fixed costs	761.13	761.13	761.13
Average fixed costs	2.76	1.62	1.30
Variable depreciation		59.40	180.36
Variable operating costs	256.85	440.85	545.46
Total variable costs	256.85	454.17	683.10
Average variable costs	.94	.96	1.17
Total costs	1,017.98	1,215.30	1,444.23
Average total costs	3.70	2.57	2.47

Figure 17 illustrates that the total costs of the 16' combine drop below those of 12' size at approximately 400 acres, but at no time within the range of timeliness of operation does the cost become less than the

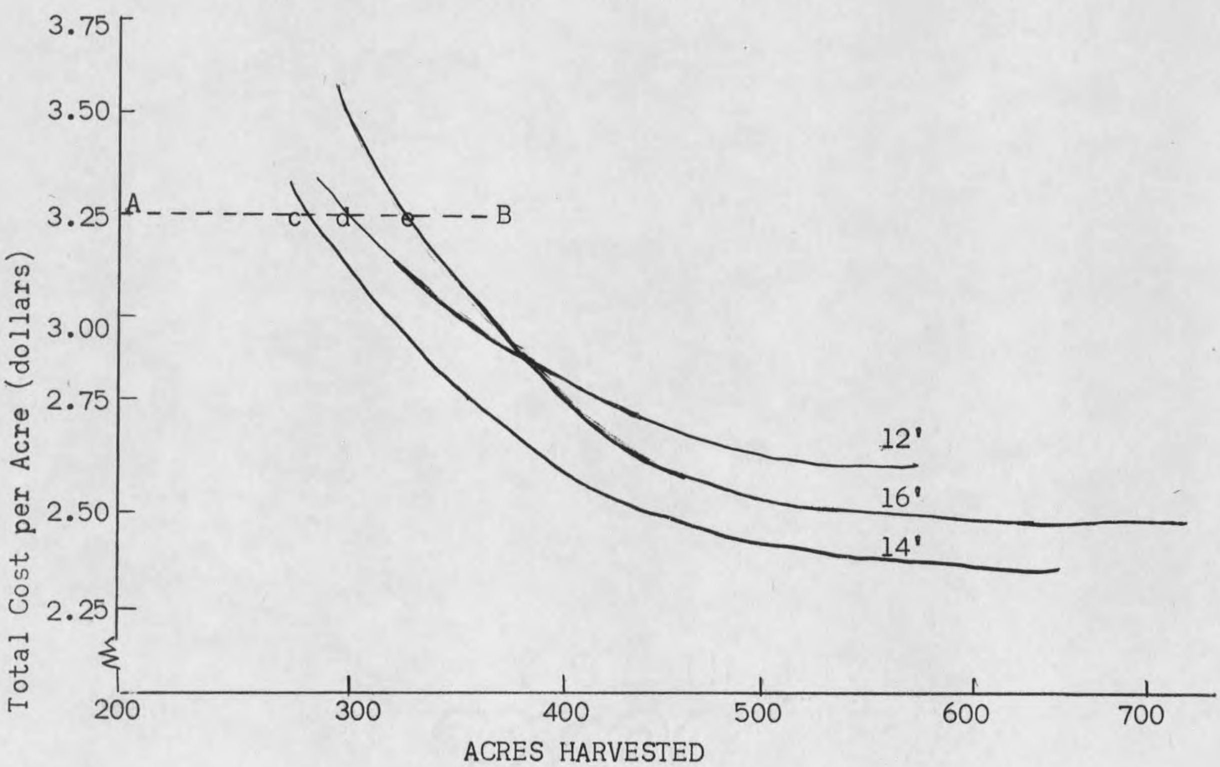

Figure 17. Total Costs per Acre for 12', 14', and 16' Self-Propelled Combines in Relation to Acres Harvested.

14' combine. At 660 acres, when the 14' combine reaches a maximum in acres which a combine of this size can harvest within the allowed time limit of fifteen days, its costs are substantially lower than the 16' combine. As a result, the 14' self-propelled combine can be considered as the most profitable machine to perform the harvesting operation under the given conditions on the 550, 944, and 2,344 acre farms.

Custom Hire

Hiring of machine services in the dryland farming area of northeastern Montana is primarily limited to the combining operation. Other machines are owned independently. Few cases were found of machine services hired to perform planting and tillage operations. As a result, the testing of alternatives in custom hiring of machine services are limited to those associated with combines.

It might be supposed that the combine service could be hired economically because of the low annual use of combines on many farms and their large investment. If the acreage of a farm is small, the combine wil be used only a short time each year and high costs will result. Whether or not it is profitable to hire combining services depends upon the relationship between costs of owning and using machines and the cost of hiring of services performed.

The current rate ($3.25 per acre) of hiring combining services in northeastern Montana is shown in Figure 17 by the line AB. The intersections of AB with the total cost curves of the 12', 14', and 16' combines provide "break-even" points between owning and hiring. Point C indicates the acreage at which the cost of hiring is equal to the cost of owning and operating a 14' self-propelled combine. Similarly D and E show, respectively, the acreages at which the cost of hiring combine services is equal to the cost of owning the 12' and 16' self-propelled combine. If the number of acres harvested annually is less than those indicated by points C, D, and E, it would be more profitable to hire combining services than to own the respective sizes of self-propelled combines.

Assuming that the costs involved in owning and operating combines are the same as those used in this study and that the cost of hiring is also identical, the dryland farmer would find it unprofitable to own a self-propelled combine if the approximate annual use is less than 285 acres. If the annual use of a combine is less than 285 acres, the total cost per acre of owning and operating a combine is greater than the current hiring rate of $3.25.

PART III

CONCLUSIONS

TRACTOR POWER AND NON-HARVEST MACHINERY

The attempt herein has been to determine an optimum machinery combination for use on dryland crop farms. Choices of machinery combinations are assumed to be based on two criteria: (1) the per acre costs involved in the use of a particular machine and (2) the ability of a machine to perform all field work within time limits imposed by climatic factors.

On the basis of these criteria, the optimum combinations of non-harvest machinery for sizes of farms tested are as follows:

(1) 550 acre farm--4-plow gasoline combination

(2) 944 acre farm--5-plow gasoline combination

(3) 2344 acre farm--two 5-plow gasoline combinations

The second and third summerfallow operations are the limiting operations to consider in providing adequate services within time limits imposed by climatic factors. Considering the second and third fallow operations as the limiting operations, the 4-plow combination will provide adequate machine services for 930 acres of cropland. The 5-plow combination would provide services for 1,172 acres of cropland.

The analysis reveals that total costs per acre of owning and operating a large 5-plow gasoline combination becomes less than the total costs of the smaller 4-plow gasoline combination before either machinery combination reaches its time limit of operation. The 4-plow gasoline combination will perform the required field operations within the time limits of operations on a farm as large as 930 acres. But the total cost per acre of the 5-plow gasoline combination becomes less than the 4-plow gasoline combination at approximately 650 acres of cropland.

On the other hand, a comparison of the 4-plow diesel combination and the 5-plow diesel combination reveals that the 5-plow diesel combination is more economical to own and operate than the 4-plow diesel combination over the entire range of farms tested.

The differences in total costs per acre for the optimum machinery combinations and the next best alternatives are relatively small:

(1) 550 acre farm --4-plow gasoline combination--two cents less per acre than the 5-plow gasoline combination.

(2) 944 acre farm--5-plow gasoline combination--five cents less per acre than the 5-plow diesel combination.

(3) 2344 acre farm--5-plow gasoline combination--two cents less per acre than the 5-plow diesel combination.

Gasoline tractors proved to be the most economical source of power on all three sizes of dryland crop farms. At no time did the reduced costs of using diesel fuel offset the higher fixed costs of owning and operating diesel power units.

HARVEST MACHINERY

Two alternatives are available for the dryland farm operator to reduce the costs of the harvesting operation. (1) If the annual crop acres to be harvested falls below 285 acres, the total cost of owning and operating a self-propelled combine is greater than the current rate of custom hire

($3.25 per acre), custom hiring would be the most profitable. (2) An increase in the amount of harvestable acres beyond 285 acres makes the 14-foot self-propelled combine the most profitable alternative. At no time, over the range of farms tested, did the costs of either the 12-foot or the 16-foot self-propelled combine fall below the total cost per acre of the 14-foot self-propelled combine.

LIMITATIONS OF THIS STUDY

The equipment alternatives considered are limited to (1) 4-plow and 5-plow gasoline tractors with given machinery combinations, (2) 4-plow and 5-plow diesel tractors with given machinery combinations and (3) ownership of (a) 12-foot, (b) 14-foot, or (c) 16-foot self-propelled combines or custom hiring in the harvesting operation.

The budget analysis technique limits the number of hypotheses which can be tested because it is so time consuming. Only the more important hypotheses can be tested. But "relative importance" itself implies hypotheses.

To keep the study from becoming too unwieldly, the testing of machine alternatives are limited to 550, 944, 2344 acre farms. Cropping practices are limited to a wheat-fallow rotation. Only the major farming operations are considered.

SUGGESTED AREAS OF FURTHER RESEARCH

The present study is limited to the spring wheat area of northeastern Montana. Additional research is necessary in such areas as the winter wheat area of central Montana to determine whether the similarities and differences yield different results in choosing among alternatives of power equipment and machine use.

Further research is also necessary in respect to various cropping practices. A wide area of study concerns the alternatives found on farms where cropping practices are not limited to a wheat-fallow rotation. Numerous dryland farms include a livestock enterprise. Others use a large percentage of the cropland for barley, flax, or oat production. Further information is necessary to determine what amount of livestock is necessary on a dryland crop farm to make it profitable to add a separate machinery combination for use with the livestock enterprise. A related problem involves the limitations of adapting crop-organized power and machinery to the requirements of a livestock enterprise.

Custom hiring is demonstrated here to provide an important alternative in power equipment and machine use. Casual observation suggests that aside from the combining operation, few such services are available for hire. More research is required to determine what conditions are necessary to increase the supply of these services. Assuming that sufficient custom services are available, the possibility exists that small farm operators can reduce costs by hiring machine services for all major field operations.

As this study indicated, accurate estimates of performance rates and fuel consumption rates are not available from the sampled area to determine the significance of varying the size of the machinery combination with a given tractor. Further research should be conducted to measure how supplies of labor and capital available to the farm operator can be more fully utilized by varying the sizes of equipment with a given power unit.

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APPENDIX

APPENDIX I

Typical Crop Organization Obtained From Sample Data for 550, 944, and 2,344 Acre Farms.

Type of Crop	550 acre farm		944 acre farm		2,344 acre farm	
	% of Total Acres	Actual Acres	% of Total Acres	Actual Acres	% of Total Acres	Actual Acres
Spr. Wheat	37	203.5	42	396.5	41.0	961.0
Barley	7	38.5	4	37.7	6.0	140.6
Oats	5	27.5	5	47.0	2.0	46.9
Flax			4	37.7	1.6	37.5
Fallow	43	236.5	39	368.5	46.8	1,097.0
Corn	4	22.0	3	28.3	2.0	46.9
Hay	4	22.0	3	28.3	.6	14.1
Total	100	550.0	100	944.0	100.0	2,344.0

APPENDIX II

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
Production Economics Research Branch

Record No. ______
Enumerator ______
Date ________

in cooperation with

THE MONTANA AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

Wheat Adjustment Studies -- land use, livestock enterprises, equipment, inventories and use, field operations and performance rates, farm labor, and operating costs.

Name ____________________ Year started as operator __________

Address __________________ County __________________

Distance to grain delivery point ____________________ Do you live on farm year-round? ______

____

1. Size and tenure of farm in 1954

Type	Owned	Rented	Total
Cropland			
Native grass (including former crop-land seeded to permanent pasture)			
Other (waste, roads, farmstead, etc.)			
TOTAL			

Rental arrangement - income-sharing ____________________

____

____

expense-sharing ______________________________________

____

____

____

No.______

Additions to farm land, 1950-1955.

Year ______________.

Total acres_____crop_____other_____rent_____bought_____.

Year ______________.

Total acres_____crop_____other_____rent_____bought_____.

Subtractions from farm land, 1950-1955.

Year______________.

Total acres_____crop_____other_____. Sold_____rented out_____.

Year ______________.

Total acres_____crop_____other_____. Sold_____rented out_____.

2. Land use, production and disposition of crops, 1954

Use	Planted acres	Harvested acres	Yield	Unit	Production	Disposition: Rent	Seed	Fed	Sold	Planted 1955
Cropland										
Spring wheat										
on fallow										
on stubble										
after row crop										
Winter wheat	1/									2/
on fallow										
on stubble										
Barley										
Oats										
Idle		xx	xx	xx	xx	xx	xx	xx	xx	
Fallow		xx	xx	xx	xx	xx	xx	xx	xx	
Hay							xx			
Pasture	xx		xx	AUM			xx			xx
new planting 3/							xx			
TOTAL CROPLAND			xx	xx	xx	xx	xx	xx	xx	
Native Grass										
Hay	xx						xx			xx
Pasture	xx		xx	AUM			xx			xx

1/Planted for harvest in 1954. 2/Planted for harvest in 1955. 3/Planted in 1954, bracket if planted with crop listed elsewhere.

 No._____

What use was made of abandoned wheat acreage? (Account for differences between "planted acres" and "harvested acres").____________________

Amount or proportion of land normally fallowed (w/o acreage allotments)___

3. Livestock enterprises, 1954

Class	Begin	No.	Bought			Home	Sales		End
	No. 1/1/54	born	No.	@	Value	used & died	No.	Ave. weight	No. 1/1/55

<u>Have you increased</u> your livestock in the past 3 years? How much?_____
Do your livestock make full use of your pasture land? (If no, why not?)__

No.______

4. Machinery, equipment, and improvements

Item (make, model, size)	Year new 1/		Annual Use	Repair cost 1954		Fuel Use Kind		
			2/					
Tractors								
Combines			Omit					
Trucks			Miles					
Other powered equipment								

Item	Year new 1/		Annual Use	Repair cost 1954
Field implements			Omit	
Haying & livestock equipment				
Mower				
Rake				
Hydraulic life			xx	
Other equipment				
Grain elevator			xx	
Fuel storage			xx	
			xx	
			xx	
			xx	
Water supply	Capacity			
Wells				
Reservoirs				
Other				

How often is oil changed or added?

Machine	Oil changed When	Oil changed Amount	Oil added When	Oil added Amount

Fencing (kind)	Length	Condition	Repair cost, 1954
Major bldgs.	Capacity		
Grain Storage			
Livestock shelter	Size		
Shop			
Other			

1/ Insert "U" in this column if machine bought used.
2/ For tractors, use other than field use.

No.________

Are these facilities adequate for present livestock enterprises? For more livestock, and if so, how much more? Water supply________

Fences________

Sheds and barns________

5. Changes in power (and equipment)
Have you changed to a larger (or smaller) model tractor for your major power unit during the past 10 years? (State 3-plow to 4-plow, 4-plow to 5-plow, etc.)________ When?________
________ Why?________

What new equipment items did you buy to use with it?________

What did you do with the old equipment?________

Do you need any other new equipment items for this tractor? (List and explain)________

When do you expect to get them?________
Have you added or reduced one or more tractors in the past 10 years?________
________ Why?________
Did you add (or reduce) equipment also? (If so, what items?)________

If added, do you need any more equipment for this (these) tractor (s)? (List and explain)________

________ When do you expect to get it?________

If equipment reduced, what did you do with it?________

No.______

6. Machinery repair practices, usual practices--(on farm, or commercial shop?)

Kind of Job	Tractor		Combine		Truck		Automobile					
	Farm	Shop	Farm	Shop	Farm	Shop	Farm	Shop	Farm	Shop	Farm	Shop
Motor overhaul												
Major repair 1/												
Reline brakes	xx	xx	xx	xx								
Overhaul ignition												
Tire change												
Hydraulic system overhaul			xx	xx	xx	xx	xx	xx				
Lubrication	xx	xx	xx	xx								
Change oil	xx	xx	xx	xx								
Weld broken parts												

1/ Transmission or differential repair; truck, car, or tractor clutch replacement; repair or replace combine cyclinder; etc.

7. Machinery depreciation and replacement

When and why do you trade in the following items of equipment (high maintenance costs; obsolete; needing equipment such as lights, hydraulic pumps, PTO, etc.; fully depreciated; dealer makes attractive offer; etc.)

Tractors ________________________________

Combine ________________________________

Truck ________________________________

Automobile ________________________________

Plow ________________________________

No.______

Oneway ______________________________

____

____

Toolbar ______________________________

____

____

Rod weeder ______________________________

____

____

____

____

____

Grain drill ______________________________

____

____

____

____

____

____

8. Field operations 1954 (1/)

Operation Kind	Machine kind & size	Tractor used 2/	Acres per hour	Amount done			Fuel per hour	Men in crew
				Acres done	Times over	Total acres		
Summer fallow								
Small grains								
Preparation for								
planting - fallow								
- stubble								
Planting - fallow								
- stubble								
Spraying								
Harvest								
Hauling grain							mpg	
Tillage after harvest								
Other crops								

1/ Operations with machines in tandem combine on one line or bracket.
2/ If more than one size of tractor on this farm, show which one usually used.

No. ________

What are your normal summer fallow operations? (Sequence and timing of operations and times over.) ____

____

____

____

What recent changes have you made in your field operations? Have any of these been caused by acreage restrictions? ____

____

____

____

____

9. Farm labor

Family labor

1954	Operator			Wife			Son-Daughter Age			Son-Daughter Age			Son-Daughter Age		
	Avail. 1/	Worked 2/	Kind of work	Avail. 1/	Worked 2/	Kind of work	Avail. 1/	Worked 2/	Kind of work	Avail. 1/	Worked 2/	Kind of work	Avail. 1/	Worked 2/	Kind of work
January															
February															
March															
April															
May															
June															
July															
August															
September															
October															
November															
December															

1/ Proportion of month available for full time work.) These may be listed as number of days, or, except
2/ Proportion of available time worked.) in case of operator, as average hours per day.

No. ________

No._____

Hired labor

Kind & Number	Dates hired From	To	Time worked	Kind of work done	Wage rate	Cost
Month						
Day						

10. Custom work (include exchange) 1954

Operation	Equipment and power furnished	Crew furnished	Work done		Cost or income	
			Amount	Unit	Per unit	Total
Your farm						
For others						

11. Miscellaneous expenses, 1954

Item and kind	Rate of use	Total used	Unit cost	Total cost
Seed bought				
Seed treatment				
Weed spray				
Fertilizer				
Insecticides				
Misc. supplies (crop)				
Feed bought				
Livestock supplies				

No.______

Item	Cost	Item	Cost	Item	Cost
Insurance crop building liability		Truck (1) license insurance (2) license insurance (3) license insurance		Farm taxes real estate personal property	

Automobile make & model__________ miles driven__________ percent farm use______

1954

APPENDIX III

Farm Machinery Survey

Name of Firm ________________________________

Address ________________________________

Person Interviewed ________________________________ Position ____________

Date ____________

Strictly Confidential

1. What is size of area served by agency? ________________________________

____

2. What percent of farmers in this area use your make as a major line of equipment ________________________________

Power Units

3. New tractor sales in 1954

a. ________ units

Model	"Stripped" Price	% of Total	Cash Sales		Time Sales	
			% of Total	% with Trade-in	% of Total	% with Trade-in

b. Equipment with new tractors

Tractor Model	Usual Equipment (Price & %)						Total Tractor Price
	Hydraulic	Starter	Lights	PTO			

c. Farm Characteristics of tractor buyers.

Tractor Model & Combinations	Acres of Cropland	Acres in Crops	
		Cereal	Forage

4. Repair, Depreciation & Trade-in for Most Popular Model

a. Depreciation

1) What is the normal life of tractor?________________

a) Used as a main power unit ________ years

b) Used as a second tractor ________ years

c) In hours of total use ________ hours

2) Market depreciation (% of original value)

a) In 1st year____________________

2nd year____________________

3rd year____________________

4th year____________________

5th year____________________

10th year____________________

b) What is the scrap value?____________________

b. Repair

1) Time preceding first overhaul _____ yrs.

_____ hrs.

2) Time intervening until 2nd overhaul _____ yrs.

_____ hrs.

3) Repair other than overhaul

a) Expense per year in year 1 : #__________

(cont.)

a) Expense per year in year 3 : # ________

5 : ________

7 : ________

10 : ________

b) Proportion of farmers who do their own repair other than overhaul ____________%

5. Trade-In for Most Popular Models.

a.

Size of Tractor	Type of Fuel Used	Age of Trade-in	% of Total Trade-In	Value Allowed	Size Traded For

b. Why did farmers trade?

Reason	% of Total

Tillage Implements

a. Sales, Trade-In, Repairs, Depreciation on Most Popular Models

Tractor Size (3-4 plow)	Make and Model of Tillage Implements	Size and Amount Sold	Price		Years of Service before being Replaced	Why Implement was Replaced	Cash Sales		Time Sales	
			Mech	Hydro			% Total	% with Trade in	% Total	% with Trade in
One Way										
Toolbar										
Duckfoot										
Drill										
Plow										

Tillage Implements

(cont.)

a. Sales, Trade-In, Repairs, Depreciation on Most Popular Models

Tractor Size (3-4 plow)	Make and Model of Tillage Implements	Size and Amount Sold	Price		Years of Service before being Replaced	Why Implement was Replaced	Cash Sales		Time Sales	
			Mech	Hydro			% Total	%with Trade in	% Total	% with Trade in
(4-5 Plow)										
One Way										
Toolbar										
Duckfoot										
Drill										
Plow										

b. Market depreciation (% of original value)

In 2nd year ________

3rd year ________

5th year ________

10th year ________

c. Proportion of farmers who do their own repair work? ____________

Harvesting Equipment

1. New Combine Sales in 1954

a. __________ units

Model & Size	Price	% of Total Sales	Cash Sales		Time Sales		Pick up Attachment		Acres harvested per year (Straight combining)
			% of Total	% of Trade-in	% of Total	% of Trade-in	% Sold with	Price	

2. Trade-in for Most Popular Models

Make & Model	Size & Type	% of Total	Age of Trade-in	Reasons for Trade-in	Value Allowed	% of Total	Traded for	
							Model	Size

3. Market Depreciation (% Original Value).

	Self-Propelled	Pull-type
In 1st year		
2nd year		
3rd year		
4th year		
5th year		

4. Normal Life of Combine

Size	Self-Propelled		Pull-Type	
	Yrs.	Acres	Yrs.	Acres
10 ft.				
12 ft.				
14 ft.				
16 ft.				

5. Proportion of farmers who do own repair work, ____________________%.

6. Characteristics of Swather Sales and Use.

a. Sales

Make & Model	Size	Price

b. Percent of farmers owning swathers ____________________

c. Percent used on more than one farm ____________________

d. Ave. Life of Swathers, Acres or hrs. ____________________

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