



Resource productivity on Montana dry-land crop farms
by Darrell Fischer Fienup

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

This thesis has a two-fold objective; namely, (1) to obtain a measure of the relative economic productivity of resources employed on Montana dry-land crop farms; and (2) to measure the returns to scale on these same farms. When economic theory is integrated with the empirical findings of the study, it is possible to draw some conclusions relating to production efficiency defined in terms of "balanced resource use." PART I defines the problem of "balanced farming" and sets forth the necessary conditions for its fulfillment. Also presented is the theory of production which is used as the basis of interpreting the empirical regression equation, making use of the historical developments of production theory, as well as a rather extensive review of empirical production function studies conducted in the past.

PART II deals with the procedures and the analysis employed in this study. Values of crop and livestock output, respectively, were expressed as logarithmic functions of variables selected as important in explaining variations in the products. These functions were fitted statistically by means of classical least squares regression, the reliability of the coefficients of the functions being measured by their respective standard errors. From these regression coefficients, elasticities and marginal productivities are computed which serve as the basis of economic interpretation. The progressive steps involved in this section extend from defining the statistical universe to drawing implications from the results.

PART III examines the limitations encountered when dealing with regression equations as related to the measurement and interpretation of the input-output relationships. Many problems still exist in this type of analysis, pointing out the need for further refinement in techniques.

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DRY-LAND CROP FARMS

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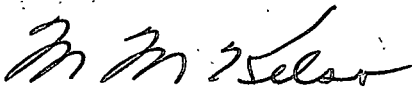
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PART I. INTRODUCTION

A. The Problem

"Balanced farming" is a term frequently encountered in the field of farm management. This term is widely used in both professional and lay literature, and, like many such widely-used terms, its meaning is hazy and ambiguous. There are about as many different meanings for the term as there are people using it. The meaning of the word "balance" in its economic sense as used in this study implies that there must be a "balance" in three major problem areas: (1) resource use, (2) enterprise selection and combination, and (3) financial management. It is recognized that these three items are not completely independent, one from the other, but that a great deal of integration exists between them.

As the title of this thesis suggests, the principle objective in this dissertation will be the isolation of the various factors of production employed on these farms in order that the productivity, efficiency, and combination of the factors of production can be determined. This objective will constitute a study of the first problem area, and to a more limited extent, the second. Enterprise selection and combination does not seem to be a major problem in the universe of dry-land wheat farms studied, for here single-enterprise farming predominates. However, limited livestock enterprises exist on a sizable proportion of the farms, and the importance of the livestock enterprise will be examined in the analysis. It will not be possible to explore the third problem because of the limitations of the data. This is regrettable because a part of the weaknesses which may be found in the first two problem areas probably could

be partially explained by financial limitations.

B. Criteria for "Balanced Resource Use"

The goal of farm management is assumed to be the maximization of net farm income. According to the theory of the firm, under competitive conditions, such a maximum will be achieved if two basic conditions are met: (1) that given levels of production be attained at a minimum cost, and (2) that the level of production be extended to the point where the marginal cost of output is equal to the price of output.

A given level of output is obtained at a minimum cost when productive services are combined so as to equate the ratios of their marginal physical products inversely with their price ratios. When this procedure is followed for successive levels of output, it is possible to derive a continuous marginal cost curve for output, which can be equated with the price of output. When this condition is met, the firm or industry is in an optimum position from the standpoint of maximizing net revenue for the firm. This is also one of the conditions of attaining maximum welfare for society as a whole.

The same solution can be found by using a similar method, which has advantages for this study. Net farm income will be maximized if the value of the marginal product of each factor is equal to its price. The value of the marginal product of a factor is found by multiplying its marginal physical product by the price of output, giving for all points on the resultant curve the increments in total revenue arising from each unit addition of a factor. It follows that the farm operator, under pure competition, will add factor units to the point where they just pay for themselves. Although

this is the optimum equilibrium point, the farm operator seldom reaches it because of lack of knowledge, uncertainty, "capital rationing", and social restrictions.

For further analysis, the difference between the value of the marginal product of a factor and cost of a factor may be defined as the "net value of marginal product" for that factor. An optimum in the combination of productive resources is achieved for a given level of output when the "net values of marginal product" are equated for all factors of production used in a given productive process. This solution satisfies the first two basic conditions previously outlined. In order to be at an absolute optimum, the "net values of marginal product" should all be zero, for here every dollar invested would yield a dollar in return. Under any circumstances, they should all be nearly the same in the incremental sense to insure an optimum resource allocation.

For this study, except for the land and labor variables, value of production is expressed as a function of inputs in value terms. Coefficients can be derived from this functional relationship which are "net values of marginal product."^{1/} The quantitative values of these coefficients, within their limitations, form measures to be compared with the criteria for "balanced resource use" in the "short run".

Previously described conditions deal with the allocation of resources in the "short run" where the scale of plant is fixed. Over the "long run" all resources are variable and the optimum size of plant becomes an import-

^{1/} From the empirical studies done in the past, the "net value of marginal product" has been referred to as the marginal productivity of a resource.

ant consideration. It will be possible to determine some measure of returns to scale from this study, from which some broad conclusions may be drawn. If decreasing returns are in evidence, farm size will at least be in the theoretically relevant economic range. If returns to scale are constant, it can be assumed no appreciable economies or diseconomies of scale exist. When increasing returns are in evidence, the firm should most generally expand the scale of operations because such action will increase the net revenue.

The problem of enterprise selection and combination will be difficult to resolve. Dry-land wheat and a few other cereal grains constitute the main enterprise. When livestock is present on these farms, it exists apart from the dry-land operation with a minimum of complementarity between enterprises. As both a crop and livestock function will be fitted to the data, it may be possible to draw some very broad conclusions as to the relative profitability of the two enterprises.

The production function will provide the basis toward which the previously described techniques of analysis are directed. Regression equations (which are the empirical counter-parts of production functions in theory), will be fitted to the data obtained from a random sample of dry-land crop farms. Outputs (in value terms) are expressed as functions of the inputs to be defined below. Derivatives of these equations will be used as empirical estimates of divergence from the criteria of "balanced farming."

C. The Analytical Framework

Micro-economics deals with the allocation of scarce resources among

competing or alternative uses. In an economy such as ours, for the purposes of economic analysis, it is assumed that people wish to maximize their satisfactions and firms wish to maximize their profits. Among other things, certain external obstacles exist which hinder the fulfillment of such a condition, one of the obstacles being represented by the physical production functions.^{1/} Therefore, a knowledge of these functions is necessarily one of the starting points in economic analysis.

The whole process of production serves the end of satisfying wants. Production economics is concerned with the analysis of alternative combinations of land, labor, capital, and management in the production process. The goal is an optimum economic combination. If various combinations of productive resources are to be examined, then something must be known about the character and nature of production. In order to arrive at any valid conclusions about the allocation of resources within and between industries, the manner in which resources are combined must be examined in order to find answers regarding the relative economic efficiency of their combination. Hence, the physical production function becomes the first thing we must know before other economic data can be applied to determine that efficiency.

The marginal productivity ("net value of the marginal product") of a particular resource, as derived from the production function, is really a measure of its efficiency in the production process. If the marginal productivity is measured in terms of net dollar addition to total product

^{1/} Boulding, Kenneth E., Economic Analysis, (Revised Edition), Harper and Bros., Publishers, New York, 1948, p. 640.

when a given resource is increased by an infinitely small unit (measured in dollars), it, in relation to such a figure for another service, shows us the relative profitability of varying that resource in comparison with variation in other resources. The firm will be making maximum profits with a given outlay when the marginal productivities are as nearly equal as possible. Due to the fact that productive services are not completely divisible, these marginal products are not apt to be exactly equal.

The marginal productivity theory states that given a combination of variable inputs in a production process, if all inputs except one are held constant, the change in total product resulting when the one input is varied is the marginal productivity of that service. Once the marginal productivity theory was established, it became theoretically possible to reduce measurable, variable input factors to a common denominator. Thus, the variation in total product can be examined when a variable input is increased or decreased by its respective unit measurement, other variables held constant.

D. The Theory of Production ^{1/}

Simply stated, the production function is a physical input-output relationship per unit of time, which may take many forms. The usual symbolic statement of this relationship appears as, $P = f(a, b, \dots, n)$ where (P) is total product and is expressed as some function of inputs (a, b, ..., n).

There may be one fixed and one variable factor combined to obtain a

^{1/} This section based on: Stigler, George J., The Theory of Price, The Macmillan Co., New York, 1947, Ch. 7. See also Boulding, op. cit., Ch. 31.

variable product. When two or more variable factors are applied to a fixed factor or group of fixed factors, the same amount of product can be obtained from various combinations of the variable inputs. This is the more realistic case where the selection and amounts of variable inputs depend on the input price relationships. To minimize costs at a given level of production, the firm will produce where the marginal rate of substitution of the variables are inversely proportional to their respective prices. The problem resolves itself to one of obtaining a given quantity of product at minimum cost (i.e., selecting the most appropriate production function, and then determining the proportions of inputs which will minimize costs). These decisions must occur simultaneously.

Stigler divides production functions into three main classes, this division being made on the basis of the nature of the coefficients of production. "A production coefficient of a given productive service is the quantity of that service necessary to produce one unit of product. Symbolically, if A produces a product of P, the $A/P = a_p$ is the coefficient of production of A in the production of P." 1/

The first hypothesis is that all production coefficients are fixed, there being only one combination of resources which will yield a product. This assumption is indeed unrealistic, as it is difficult to visualize obtaining a zero product by varying the proportions of the inputs by only a small degree from a fixed ratio.

The second possibility is that all of the production coefficients are

1/ Ibid., p. 111.

variable. In this situation, the same quantity of product can be secured by varying the amounts of any one input when the amounts of the other inputs are varied in a compensatory manner. This hypothesis implies substitution between factors of production. Here time becomes the crucial element, because over time it can be assumed that the entrepreneur can vary his production function or technique. An example might be producing a given product from a given piece of land. The land may be improved by increasing its ability to absorb inputs, (i.e., its capacity for production). This could take the form of improved soil structure. Neither does management remain constant over time. Most economists accept the proposition that all of the production coefficients are variable in the "long run".

The third possibility is that some of the production coefficients are fixed and others variable. A variation of this idea is that the inputs may be in fixed relationships with one another and not with the product. Here, the inputs could be combined in only one proportion, but a variable product could result. Stigler illustrates this point with the example that a delivery truck may "require" only one driver, but the combination can deliver a variable amount of goods. ^{1/} These assumptions do not generally hold if the entrepreneur has sufficient time to make adjustments in the use of all his resources.

There are certain general laws which describe the characteristics of the production function, these being the laws of return. These laws are

^{1/} Ibid., p.112.

generally known as the law of variable proportions or diminishing returns, and the law of returns to scale.

The law of diminishing returns states that as successive amounts of a variable factor are increased by equal increments, other variables held constant, the resulting increments in total product will eventually decline. Evidently, this is generally true in all processes of production.^{1/} By substitution of resources is meant that to some degree resources will substitute for one another in producing any given product. This is illustrated by the contour lines drawn on a production surface where various combinations of variable inputs X and Y will give the same product.

In the scale analysis, all resources are variable. If, when all inputs are increased in the same proportion, output increases in the same proportion, then constant returns to scale exist. If total output increases proportionately greater, then increasing returns exist, and, if total output increases proportionately less, then decreasing returns to scale exist. Returns to scale on the physical production surface is shown by the movement on the surface above a straight line drawn on the XY plane through the origin. When moving on any straight line through the origin, we are changing X and Y by constant respective percentages. The resultant percentage change in output compared with the percentage change in inputs determines the conditions of scale.^{2/}

Production functions can vary from the very simple to the extremely

^{1/} Hopkins, John A., Elements of Farm Management, Prentice-Hall, Inc., New York, Third Edition, 1949, Chapter 10.

^{2/} For a diagrammatic illustration see: Boulding, op. cit., p. 681.

complex, depending on the number of variables and their relationship to each other. The most simple would be linear with only two variables and is illustrated in two dimensions. A production function of this type would show constant marginal returns to the variable input throughout the whole scale of operations. This assumption is not in accord with our laws of return, at least not over the entire range.

When progressing to the three or more variable analyses, it is possible to obtain a more complete picture of the process of production. Almost every production process combines at least two variable resources of production. To be represented graphically,^{1/} this analysis must be pictured in three dimensions where the two variable inputs are shown on the axis of the base plane with the product resulting from various combinations of the two variables shown as the height above the base of the structure. With this type of analysis, all of the laws of return, including substitution effects in producing a given output, can be shown.^{2/}

^{1/} Ibid., p. 679.

^{2/} It will be noted that derived from the general symbolic production function $P = f(a, b, \dots, n)$ we can derive an equation

$$(dP = \frac{\partial P}{\partial a} \cdot da + \frac{\partial P}{\partial b} \cdot db + \dots + \frac{\partial P}{\partial n} \cdot dn)$$

which is the same as $(dP = MPP_a + MPP_b + \dots + MPP_n)$. The marginal physical productivity $(\frac{\partial P}{\partial a})$ is the slope of the total product curve at a given point on the production surface with respect to input a, when all other variables are held constant. When the marginal physical productivity is multiplied by the quantity of that service $(\frac{\partial P}{\partial a} \cdot a)$

the marginal physical product of that service is obtained. If the sum of the marginal physical products is equal to the change in output,

E. Historical Development

The awareness of problems arising in the process of production has been present since earliest recorded history. In the Bible under the "Book of Genesis," it is told that Abram and Lot saw fit to split their flocks and go their separate ways, all because their holdings had become too great for them to subsist together at optimum advantage.^{1/} Aristotle made reference to the technique of good management when he wrote concerning the active participation of the owner in caring for his property.^{2/} There was also a hint of the productive advantages of the division of labor when Aristotle wrote that the man who wishes to practice economy should "be fully acquainted with the places in which his labour lies."^{3/} In the writings of Plato, the special advantages of specialization in production and in the promotion of a society received emphasis.^{4/} These few examples illustrate that people did think of production problems even though the economic production theory or economics itself had not yet been developed. It was probably with the rise of mercantilism that people

(^{2/} continued from p. 16.) then constant returns to scale are indicated, but if the sum is more or less than the change in output (dP), increasing and decreasing returns, respectively, are evident. When constant returns to scale exist, a linear, homogeneous function is implied. By holding one variable constant, it is possible to observe the increase or decrease in the marginal physical product (MPP) of the variable being varied.

^{1/} Genesis, XIII, Vs. 2 - 6.

^{2/} The Works of Aristotle, Vol. 10, *Oeconomica*, 1345a.

^{3/} *Ibid.*, 1345b.

^{4/} The Dialogues of Plato, Vol. 3, *Republic*, p. 50.

became increasingly aware of economic problems, and the science developed. Heretofore the accumulation of wealth was regarded with disfavor because of the Church, but with the development of mercantilism, the attitude toward wealth changed, with resultant increased interest in economic affairs.

1. Contributions in Economic Theory.

So-called "modern economics" had its inception in the eighteenth and early nineteenth centuries. As people began to study "wealth," they also inquired into its production. What things constituted wealth, and what forms of man's activity were productive? The French Physiocrats held the view that only land was productive, that it, alone, brought forth a "surplus above maintenance." Adam Smith asserted that some labor was productive, while some other forms of labor were not. Only when the product produced was of a durable nature could the labor expended in its production be called productive. The socialists, especially Karl Marx, thought that labor alone gave rise to wealth; therefore, the disposition of wealth should be in the hands of those who produced it. However, since the work of Adam Smith, most economists have proposed that all resources combined in production may be termed "productive". This is the view most generally accepted today. Capital and management also made their appearance as productive factors with the advancement of economics. We now have the four generally accepted factors of production: Land, labor, capital, and management.^{1/} Entrepreneurship may also be included as a factor, the returns to which may be considered as the result of bearing uncertainty. The return to this factor is a residual quantity and may be positive or negative

^{1/} Whittaker, Edmund, A History of Economic Ideas, Longmans, Green and Co., 1947, Chapter VIII.

after returns have been allocated to the other factors of production.

Leon Walras was the first economist to give a general symbolic statement of the production function. Although he assumed fixed coefficients of production and no-profit entrepreneurship, his work is most important. Walras is probably to be commended most for his development of the theory describing the general nature of equilibrium. He has the distinction of being the first economist to show "that under perfect competition, full employment of resources is compatible with the desire of each individual to maximize the returns from his resources."1/

Philip H. Wicksteed's great contribution was the reduction of all factors of production to a common measure, that being service rendered. Here the marginal efficiency of a factor determined its value, formulated by the effect upon the product of a small increment of that factor, all others remaining constant. Wicksteed proposed exhaustion of product,2/ but went about to prove it by use of the classical theory of rent rather than by

1/ Stigler, George J., Production and Distribution Theories, The Macmillan Company, New York, 1949, pp. 241-242.

2/ There has been considerable conflict in the development of distribution theory regarding the validity of the concept that all productive agents are rewarded in accord with their marginal products, thus exhausting total product. This branch of theory fell into two parts. The exhaustion of product question did not confront the proponents of the residual theories. Here at least one residual claimant to the total product was assumed. Rent was nearly always considered a residual with "profit" as a second claimant. Although the exhaustion of product postulate was no problem for the residual theorists, it was an explicit assumption for who held the other view. Much controversy followed, and it was with the application of Euler's Theorem that justification of the latter view gains validity. For a summary of this discussion, see *ibid.*, Chapter 12.

using the Euler Theorem. He chose to show that rent as a residual equals rent as a marginal product.^{1/} Another assumption was a linear homogeneous production function; i.e., as all factors are increased in a given proportion, total product will increase in the same proportion. Euler's Theorem holds here only if the price of the commodity remains constant with respect to price of inputs. The price of the product will remain fixed only if there is a corresponding increase in the market. Such a conclusion is obviously unwarrantable; another explanation is forthcoming. If perfect competition exists, the output of a single firm will be negligible in its effect on the price of the product.

Barone did significant work in production theory which is worthy of mention.^{2/} His analysis dealt only with stationary equilibrium, which means a fixed quantity of resources. The basis of his work is the law of diminishing physical productivity. His solution of the production problem is essentially the same as held today, i.e., that the entrepreneur will maximize returns if each factor is used up to the point where the increment of cost of the factor equals the increment of return to the entrepreneur. Time consumed in the production process was also a part of Barone's analysis. Here every factor of production was rewarded in accord with its marginal product less interest on the corresponding part of the capital of anticipation.^{3/}

^{1/} Ibid., pp. 324-330.

^{2/} Ibid., pp. 356-362.

^{3/} The capital of anticipation may be considered as the increased value of an investment resulting from a period of waiting for returns to accrue.

Pareto's main contribution here was his criticism that there is not complete substitutability of factors in the production process, but that some hold in fixed relationship to each other. In other words, some coefficients of production are fixed, others variable.^{1/} Although this is a valid argument, its importance is questionable. Although there are some processes of production which involve fixed factor relationships, these cases are economically trivial. Besides, it seems perfectly logical to assume some variability in production coefficients over the "long-run". This variability occurs with advancement in technology ^{2/}, and the accumulation of capital goods.

Knut Wicksell raises the question of the indivisibility of productive services with regard to a linear homogeneous function. When large and continuing indivisibilities are present in the firms of an industry, these firms will be operating under continuously decreasing "long-run" average cost curves. Competition will be unstable.^{3/} To hold true, this relationship must consist of technological considerations alone. It may be well to point out at this time the human factor which is really the cause of the limitation of indefinite increase in the scale of the firm. Human abilities are limited and especially subject to diminishing returns to management. There comes a point where the advantages of specialization

^{1/} Ibid., p. 364-365

^{2/} An advancement in technology has taken place when the same (or more) product can be produced with less (or the same amount of) inputs. This means the production surface has shifted to a higher plane.

^{3/} Ibid., p. 381.

are overtaken by the complexities of red tape. Therefore, most certainly, the firm will ultimately be faced with decreasing returns to scale.

It is only in an entrepreneurless economy that the linear, homogeneous production function will hold and that Euler's Theorem is applicable. The entrepreneurial role will disappear only in a completely stationary economy where the stocks of resources, technology, and the tastes of people are fixed. All production would become a matter of routine. However, it is under a dynamic economy which we live, where decision making and ever present uncertainty exist. Anticipations of profit determine production and the returns to entrepreneurship are expressed as a residual. This does not discredit the fact that all other productive services may be rewarded in relation to their marginal productivities.

2. Empirical Studies.

The use of production functions in empirical studies is a somewhat recent development. This field of study has developed with advances in econometrics. Exploration in production function analysis was pioneered by Professor Paul H. Douglas of the University of Chicago, who is now a United States Senator. His first work appeared in 1928 and was composed of a production function for all manufacturing in the United States.^{1/} This study was co-authored by C. W. Cobb of Amherst College. Here a function was fitted to all manufacturing by using the indices of the relative amounts of capital, labor, and physical output employed in manufacturing for the years 1900-22. The year 1899 was considered as the base

^{1/} Douglas, P. H. and Cobb, C. W.: "A Theory of Production", American Economic Review, vol. 18 (1928) supplement, pp. 139 ff.

year with a value of 100. The general symbolic function of $P = f(L, C)$ was used. These three variables as included in the equation, are denoted respectively as: (P) which is the index of physical volume of manufacturing; labor (L) which is the index of the average number of wage earners in manufacturing; and capital (C) which is the index of the fixed capital in manufacturing.

He fitted a function linear in the logarithms by least squares regression. This has come to be the method followed in most subsequent studies. Douglas started with the assumption that the sum of the regression coefficients is one, thus assuming constant returns to scale. His function in non-logarithmic form is expressed as follows:

$$P = 1.01 L^{0.75} C^{0.25}$$

The exponents are also the elasticities of the dependent variable product in its relation to the independent variable inputs.^{1/} Interpretation of this function then indicates that if labor is increased by one per cent, total product will increase by $3/4$ of one per cent. Likewise, when capital is increased by one per cent, product will be increased by $1/4$ of one per cent.

If the production function is linear and homogeneous, then it is a matter of complete indifference which size of plant the entrepreneur may build, for every size of plant is just as efficient as every other size. All sizes of plant will have the same minimum "short-run" average cost. When output doubles, then total costs double. Even when the assumption

^{1/} An elasticity of a particular independent variable is the percentage change in total product variable when the variable is increased by one per cent.

of a linear homogeneous function was not made, the sum of the elasticities made by Douglas in later studies were very close to one, indicating constant returns to scale. Although Douglas and his associates made numerous other studies, this one should be sufficient for the purposes of this study.

Gerhard Tintner of Iowa State College was one of the pioneers in using statistical production functions to analyze farm data. In his original study,^{1/} Dr. Tintner used the business records from 609 Iowa farms for the calendar year 1942. The function fitted to the data was linear in the logarithms, being essentially the same function Douglas had used. Tintner's reasons for using this function rather than any other were as follows: "...it gives immediately elasticities of the product with respect to the factors of production; this form of the production function permits the phenomenon of decreasing marginal returns to come into evidence without using too many degrees of freedom; and finally, if the errors in the data are small and normally distributed, a logarithmic transformation of the variables will preserve the normality to a substantial degree."^{2/} Tintner used total product (X) measured by gross profits for the dependent variable. Independent variables included: land (A) measured by total acres; labor (B) measured in man-months; value of farm improvements (C); liquid assets (D), including livestock, feed, seed, and supplies; and working assets (E) including breeding cattle, horses, tractors, crop

^{1/} Tintner, Gerhardt: "A Note on The Derivation of Production Functions from Farm Records", Econometrica, XII, No. 1, (January 1944) 26-34.

^{2/} Ibid., p. 26.

machinery, livestock equipment, special machinery, trucks, farm share of the automobile; and cash operating expense (F), including livestock expense, feed purchased, repairs, fuel, and oil for all equipment on the farm.

The regression coefficients as computed were as follows: $A = 0.288$; $B = 0.158$; $C = 0.054$; $D = 0.212$; $E = -0.005$; and $F = 0.159$. All these coefficients are significant at the 5% level of probability except for working assets (E), which had a negative value. This is to say that a value of -0.005 for (E) has the probability of arising by chance more than 5 times out of a 100, if the true value is zero. Therefore, it can be concluded that the negative value of working assets could have arisen by chance and apparently has little statistical significance in this production equation. All of the elasticities are less than 1.0, so decreasing marginal returns are in evidence. Also, the sum of the elasticities of all inputs is less than 1.0 (0.866), thus indicating decreasing returns to scale. Another regression equation was fitted to the data under the assumption that constant returns to scale existed (sum of elasticities equal to 1.0). When the sums of the squared residuals of both functions were compared, it was found that the difference was not significant at the one per cent level. We can then make the assumption that constant returns to scale exist.^{1/}

This result tends to substantiate the finding of Douglas which indi-

^{1/} Tintner, Gerhardt: Econometrics, John Wiley and Sons, Inc., New York, 1952, pp. 89-91.

cated a linear, homogeneous, production function.^{1/} It must be recognized, however, that the Iowa farms observed in this study were not "average" but somewhat above. This may be attributed to the fact that record keeping farmers are usually more prosperous than the average.

A further study of "Production Functions Derived from Farm Records" by Tintner and O. H. Brownlee ^{2/} is closely patterned after the previous study and the results are similar. Detailed farm records of 468 Iowa farmers for the year 1939 were used. The sample consisted of above average farmers, a "Cobb-Douglas" function was used, and variables were classified in the same way as in Tintner's previous study. Elasticities as computed for the individual factors were all less than one and the sum of all was almost 1.0 (0.9871), thus indicating constant returns to scale.

Marginal productivities of the variables were also found.^{3/} The Marginal productivities measured at their geometric means and derived from the elasticities were found to be: land, 0.0981; labor, 0.0877, improvements, 0.0449; liquid assets, 0.1790; working assets, 0.1585; and cash

^{1/} This does not mean that a linear, homogeneous function exists over the entire range of possibilities, but only over the range actually observed.

^{2/} Tintner, G. and Brownlee, O. H.: "Production Functions Derived From Farm Records", Journal of Farm Economics, vol. 26, 1944, pp. 566 ff.

^{3/} A marginal productivity indicates the net addition to total product in terms of dollars when a particular resource is increased by the amount of one dollar.

operating expenses, 0.2808. Interpreting this would mean that on the average if one additional dollar was invested in land, we could expect \$1.10 in return; if one dollar was spent on labor, we could expect \$1.09 in return, etc. In terms of the marginal productivities of the factors, it would be most profitable for the average (at the geometric mean) of the farms studied to spend additional money for cash operating expenses where the return is \$1.28 for every dollar spent.

The previous work was followed by a study conducted by Earl O. Heady.^{1/} The production functions developed by Heady were similar to all previous work, although he divided the independent variables into somewhat different classifications. Also, this is a study made from a random sample of Iowa farms. A complete record of all operations and transactions for the year 1939, including beginning and ending inventories, made up the answers on the schedules. Seven hundred thirty-eight (738) farmers were interviewed. A function linear in the logarithms was developed, and is expressed in the following form:

$$\log X = a + b_1 \log A + b_2 \log B + b_3 \log C + b_4 \log D + b_5 \log E.$$
^{2/}

Inputs and outputs were classified in the following manner. Total product included the sum of all cash sales, home consumption and changes in inventory. Inputs included: the value of land and buildings; months of labor used; machinery and equipment value, including the cost of maintain-

^{1/} Heady, Earl O.: "Production Functions from a Random Sample of Farms," Journal of Farm Economics, Vol. XXVIII, No. 4, November, 1946, pp. 989-1004.

^{2/} The b values are regression coefficients or elasticities.

ence and operation; the value of livestock on hand and purchased, including feed fed and livestock expense; and cash operating expense, including fertilizer, twine, custom work and other miscellaneous operating expenses. These independent variable inputs were designated as A, B, C, D, and E, respectively, and the dependent output variable called X.

Separate functions were figured for crop, hog, dual purpose and dairy, general, and special farms. Functions were also figured for small farms and large farms, the division being made on the basis of total capital employed. For all farms, more than 78% of the variance in total output was associated with the inputs listed. It must be remembered that this includes an average of all farms. The unexplained portion could be attributed to different techniques employed on the farms, the exclusion of the management variable, and error in reporting the original data.

The regression coefficients which were calculated for the individual factors of production are also the elasticities of these factors. They show the average percentage change in total product which might result if the input of the particular resource is increased by one per cent. The elasticities as computed for all farms were as follows: land, 0.2316; labor, 0.0282; equipment, 0.0844; livestock and feed, 0.4767; and miscellaneous operating expense, 0.0317. The livestock and feed coefficient was by far the largest. An increase in the livestock and feed input of one per cent would give a .4767 per cent increase in total product. The next highest coefficient was for land, it being .2316. In each classification of farms diminishing marginal returns was indicated for the individual production factors as the elasticity in each case was less than one.

The sum of the elasticities for all farms as well as the various breakdowns was less than 1.0 (.8526), hence diminishing returns to scale were indicated. It was expected that increasing returns to scale would be found on the "smaller" farms, but such was not the case. Such an assumption supposes that small farms could profit by the use of specialization, diversification, larger machines, etc. A previous study which was conducted on larger farms had also shown decreasing returns to scale.

Marginal productivities were computed for each group of farms. For all farms they appear as follows: land, 0.0465; labor, 0.0791; equipment, 0.2013; livestock and feed, 0.8390; and miscellaneous operating expense, 0.3931. These figures give definite clues as to efficiency in the combination of resources. In the category of all farms, it was shown that the net returns to be expected from land for an extra dollar invested would be 4½ cents, 8 cents for labor, 20 cents for all equipment, 84 cents for livestock and feed, and 39 cents for miscellaneous operating expense. This would indicate that livestock would be the most profitable enterprise to expand (i.e., additional money the farmer has, or can borrow, should be invested in livestock first because it will pay him \$1.84 for every dollar increase in cost). It would also pay him to reduce his costs in some categories to the place where the marginal productivities from all resources are more nearly equal, thus maximizing net farm income with a given outlay.

The marginal productivities were highest on the most productive land which is the cash grain area of the state. Since these marginal productivities relate back to the land value, it appears that relative to the

rest of the state, land is under-capitalized in the cash grain area. The marginal productivity of land gives us a measure of what rents on various types of land should be. Theoretically, each factor of production is rewarded in accord with its marginal productivity. At a return of $4\frac{1}{2}$ cents for all land, then the landlord can expect to receive 9 dollars in net rent on land valued at \$200 an acre. This is the return to land and improvements accruing to the land owner if these are his only contributions to the farm enterprise.

Labor showed a rather low marginal productivity. This can be partially explained by the fact that there was a surplus of labor on Iowa farms in 1939; also no differentiation was made as to the capacity of the workers in regard to age and physical ability. In addition, farmers tend to report more man-months of labor than is actually spent.

The returns to machinery and equipment were highest in the poorer areas of the state. This can be attributed to the fact that these areas were largely under-mechanized in 1939. However, a fairly high return to machinery and equipment was indicated for the state as a whole.

Dr. Heady pointed out the limitations of the technique of fitting a production function to empirical data. One of the main difficulties is the classification of independent variables into categories which are really independent. So many of the production processes within the farm firm have complementary relationships. Therefore, when a high degree of correlation exists as predetermined by statistical analysis of the variables, such variables should be combined into one independent variable.

Also, it should be noted that the regression coefficients as computed

apply to the average of the farms in the universe studied, and not a single farm. Therefore, the regression coefficients and marginal productivities can only be regarded as applying to the average of the farms studied and not individual units. Dr. Heady further points out that more reliability can be attached to the results when comparisons of similar productive services are made between groups of farms rather than between the factors of production within a group of farms.

A recent production function study was conducted by Hu Harries.^{1/} It is perhaps the most relevant to this thesis, as the universe of farms used in both studies is composed of dry-land wheat farms. Comparison of the results should prove the most interesting. Data for Harries' study were gathered from the records of 194 farmers in the Eyebrow-Lacenda section of Saskatchewan, Canada, for the year ending April 30, 1940. These farms were all in Land Class III, and the techniques and type of farming operation was held as nearly constant as possible. This was done to insure more homogeneity of "non-economic" factors such as climate, moisture, sunlight, and insects. Also, such a classification gives more significance to the "economic" independent variables in the function. These variables were classified as follows: (A) average real estate investment; (B) average livestock investment; (C) average machinery investment; (D) months of labor; and (E) cash operating expense. Both a linear multiple regression equation and a logarithmic function of the Douglas type were fitted to the data. For the

^{1/} Harries, Hu: "Development and Use of Production Functions for Firms in Agriculture," Scientific Agriculture, Agricultural Institute of Canada, XXVII, No. 10, (October, 1947), 487-493.

former, the equation is: $X_c = 471 \neq 0.045 A \neq 0.2340 B \neq 0.359 C \neq 15.823 D \neq 1.922 E$, and the latter; $\log X_c = 0.04 \neq 0.18 \log A - 0.03 \log B \neq 0.18 \log C \neq 0.06 \log D \neq 0.75 \log E$. It will be noted that the sum of the elasticities of the logarithmic function is 1.14. This indicates increasing returns to scale. This is one of the few studies that has shown this phenomenon. Perhaps this is not too surprising when the nature of a dry-land wheat operation is examined. It is generally recognized that wheat farms in the Great Plains are on the whole too small. With modern machinery and methods of farming, the acreage one man can handle has increased considerably. Shifting of resources to make up larger and more profitable units has undoubtedly suffered a time lag.

On the basis of the sum of elasticities and actual observation of existing conditions, it would be concluded that farmers are operating under increasing returns to scale. However, we do not know that 1.14 is significantly different from 1.0 until it has been tested. On the basis of the correlation coefficients for the logarithmic and the multiple linear correlation analysis, we can be more skeptical of the conclusion that increasing returns to scale exist. The correlation coefficient for the former is 0.85, and for the latter, 0.88. With due regard for the methodology involved, more variation in the dependent variable is explained with a linear equation than with the logarithmic function. The coefficients for both equations are significant at the 1% level of probability. It would be interesting to develop a function of the type: $\log Y = A \neq BX \neq CX^2$ --- to determine if these farms are operating under conditions of in-

creasing marginal returns.^{1/}

Several of the limitations as pointed out by Mr. Harries are: (1) the study is of a static nature and does not use a dynamic technique, (2) management is not included in the analysis, (3) a high degree of relationship between the input and output variables is not necessarily a causal relationship. Therefore, the results obtained should be carefully analyzed before any statement of causal relationships can be made. Also, even though the unexplained variation is not statistically significant, it may be important from an economic standpoint.

Table I. Comparative Elasticities of Production Function
Variables Derived from Farm Data ^{2/}

Factors	Tintner*	Tintner & ** Brownlee	Heady***	Harries****
Land	0.288	0.3434	0.2316 ^a	0.18 ^a
Improvements	0.054	0.0431		
Labor	0.158	0.2364	0.0282	0.06
Liquid Assets	0.212	0.1729	0.4767 ^b	-0.03 ^c
Working Assets	-0.005	0.0795	0.0844 ^d	0.18 ^d
Misc. expense	0.159	0.1118	0.0317	0.75
Sum of the Elasticities	0.866	0.9871	0.8526	1.14

* Derived from Iowa farm records (1942)

** Derived from Iowa farm records (1939)

*** Derived from random sample of Iowa farms (1939)

**** Derived from records of Canadian dry-land crop farms (1940)

a - and Improvements

b - Livestock and feed

c - Livestock only

d - Machinery & equipment

^{1/} If the correlation coefficient of this equation was below 0.88, it could be concluded the linear function provides the best fit.

^{2/} With the exception of working assets under Tintner's study, working assets and improvements under Tintner's and Brownlee's study, labor under Heady's study, and livestock and labor under Harries' study, the elasticities are significant at the 5% level of probability.

By way of summary, it should be well to bring the results of previous studies together under one heading. Here, an attempt will be made to briefly summarize and compare the elasticities (regression coefficients) and the marginal productivities derived in past studies.

Any conclusions drawn must necessarily be broad ones. The independent variables of the various studies do not all include the same things, nor are they all measured in the same way. Also, different areas and sampling techniques were used. However, the sums of the elasticities are all close to one. ^{1/} This would indicate that for the Iowa farms, constant returns to scale may exist.

Elasticities have been classified categorically under the factor headings that Tintner used in his study of farm records for 1942. As will be noted in the Table, the classification of variables (factors) differs between studies. For the purposes of comparison of the elasticities, only Heady's and Harries' studies will be used. It is doubted if meaningful results could be obtained by a comparison of all four studies due to complications previously mentioned.

Elasticities do not serve as measures of efficiency; they do, however, serve as a basis for deriving the marginal productivities from which conclusions relating to efficiency are derived. The labor variable does not give a significant result in either study. Nearly all studies have shown low elasticities for labor. This may be due to farmers overestimating their labor input; also, it tends to substantiate the thesis that an "excess"

^{1/} It will be noted that the sum of the elasticities in Harries' study is more than one.

labor supply exists on most farms.

Livestock was not a significant variable on the dry-land wheat farms; in fact, its elasticity is negative. However, on Iowa farms, an increase in livestock investment would provide a greater increase in total product than any other variable. This tends to show the relative profitability of an increased livestock enterprise on Iowa farms. Machinery and equipment showed a higher elasticity on the wheat farms than the Iowa farms. Machine farming should hold a special advantage on wheat farms because large scale machine use is especially adapted on this type of operation. It could be expected that the elasticity of machinery could have been even higher. However, most of these farms were probably already highly mechanized by 1940. The exceptionally high elasticity of miscellaneous expense on the wheat farms suggests important relationships. Since it represents an aggregate of inputs, few straightforward conclusions can be drawn. Furthermore, in relation to all elasticities, it must be remembered that Heady's study was taken from a random sample of farms using the survey method, while Harries' study was from selected farm records. Therefore, if Harries' study had been a random sample, the difference between elasticities of the two studies could have been even wider.^{1/}

^{1/} Record keeping farmers are usually the most progressive, and therefore make better use of resources under their command. Hence, it can be supposed that they are operating at a higher point on the total product curve, thus giving lower values for the elasticities of the variables.

Table II. Comparative Marginal Productivities of Production
Function Variables Derived from Farm Data 1/

Factors	Tintner &* Brownlee	Heady**
Land	0.0981	0.0465 ^a
Improvements	0.0449	
Labor	0.0877	0.0791
Liquid Assets	0.1790	0.8390 ^b
Working Assets	0.1585	0.2013 ^d
Miscl. Expense	0.2808	0.3931

* Derived from Iowa farm records (1939)

** Derived from random sample of Iowa farms (1939)

a - And Improvement

b - Livestock and feed

d - Machinery and equipment

Only the marginal productivities of two studies appear in the above table as only for these two were marginal productivities derived. Again, comparison is difficult because of different classifications of inputs.

When comparing the two tables, it will be noticed that the marginal productivities are more nearly equal on the study taken from farm records than those of the random sample. This, itself, is an indication that resources are more efficiently combined on the farms which kept records. In the random sample, livestock and feed show an extremely high marginal productivity. On the average of farms, then, the livestock enterprise should be expanded. Both a better allocation of resources and more net income to the average farm operator should result. Land and labor both show a higher productivity on the record keeping farms. Farms who join record keeping associations are ordinarily the first to adopt new techniques and improved

1/ All marginal productivities listed are significant at the 5% level of probability.

production methods. This is probably one of the reasons record keeping farms show higher marginal productivities.

Some clarification concerning the difference between the marginal productivity and elasticity needs to be made. The elasticity is a constant and holds throughout the range of observations. It shows the conditions of return to each factor, and is a percentage change in output resulting from a 1% change in input. The sum of all elasticities indicates returns to scale. Marginal productivities are evaluated at a given point, (e.g., at the geometric means), on the total product curve and are a ratio between two value terms.

PART II. EMPIRICAL INVESTIGATION

A. Sampling Procedure

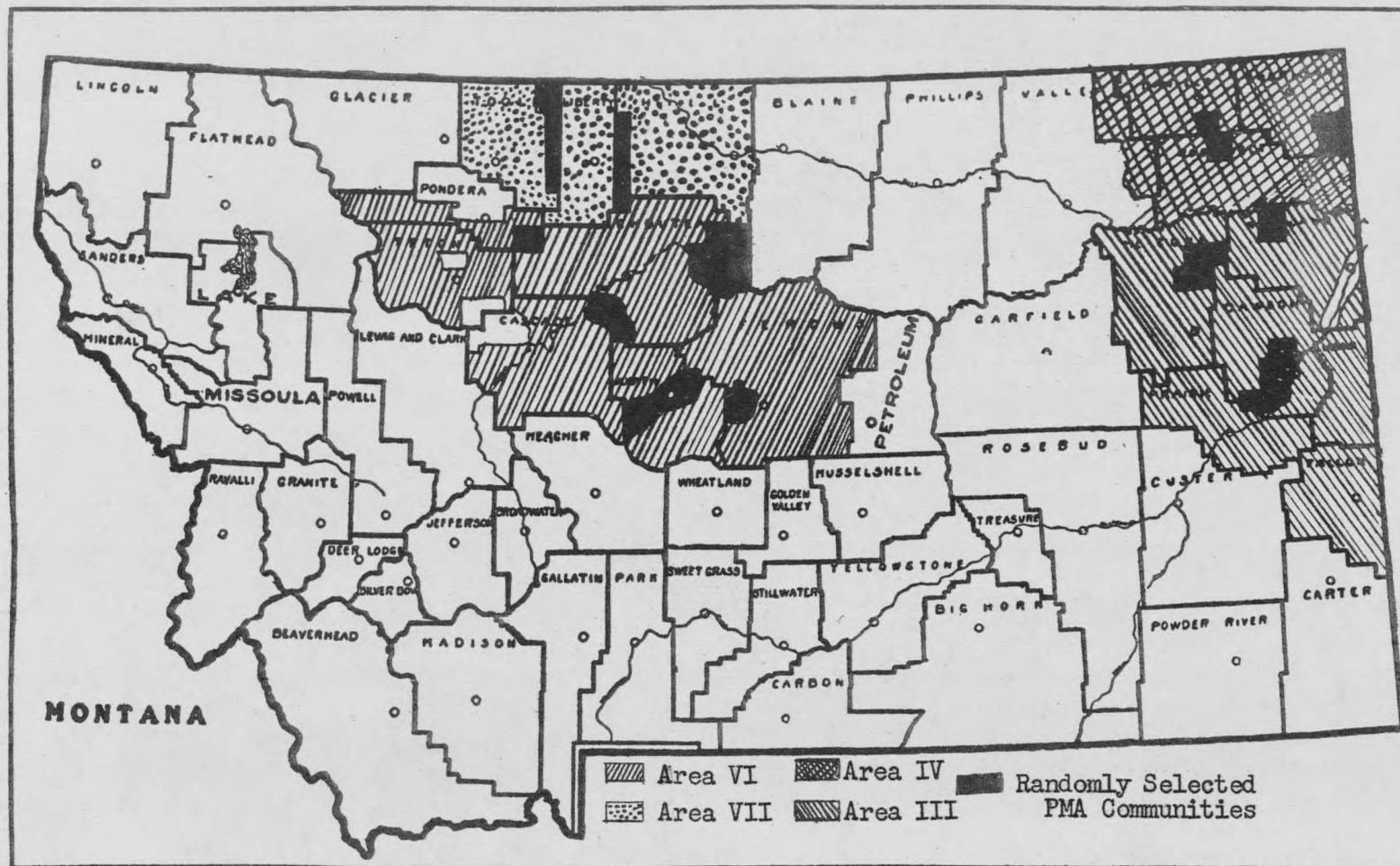
As this is a study of resource productivity on Montana dry-land crop farms, the first necessary step was to define the limits of the universe from which a sample could be drawn. The state has been divided into major farming areas by the Bureau of Agricultural Economics, 1/ each area representing certain types or combinations of types of agriculture. Areas III, IV, VI, and VII constitute the universe which represents both winter and spring wheat areas with their accompanying variations in farming practices and climate conditions. It is assumed the universe, as designated, will adequately reflect the range in dry-land crop farming conditions. These areas are outlined on the following map.

The Production & Marketing Administration (hereafter referred to as the PMA) has subdivided all the counties in the state into PMA "communities", defined in terms of a trading area. This break-down of the counties into sub-areas provided the basis for drawing a random sample without having observations scattered over the entire universe. Furthermore, the PMA had complete listings of all farm units in the universe as defined. 2/

PMA communities in which more than half of the farms were irrigated

1/ Farm Adjustments in Montana, (Graphic Supplement), USDA, BAE, Washington, D. C., July, 1940.

2/ The PMA assured us that their records would include more than 99% of the farm operators.



III. Map of Montana Outlining the Communities Sampled Within the Universe as Defined

were eliminated from the universe. The next step consisted of setting up the procedure for drawing the sample.

It was arbitrarily decided that the sample should consist of approximately 150 interviews. Furthermore, to insure adequate representation of each of the major farming areas, it was necessary to apportion the number of observations among these areas on the basis of the number of dry-land farms per area. ^{1/} The respective numbers of farms in each area are indicated in the following table.

Table IV. Number of Dry-land Farms in Selected Major Type-of-Farm Areas

Area	Number	Per cent of Total
III	6,227	22.1
IV	6,597	23.5
VI	10,703	38.1
VII	4,582	16.3
Total	28,109	100.0

Numbers of observations were apportioned to each area by multiplying its respective "Per cent of Total" by 150. This gives approximately 33, 35, 57, and 25 observations from Areas III, IV, VI, and VII respectively. It was then arbitrarily decided to take twelve interviews from each community. Three were picked in Area II, three in Area IV, five in Area VI, and two in Area VII. Thus, thirteen communities were selected and 156 interviews were taken. A table of random numbers was

^{1/} When taking a proportional sample from each area on the basis of the number of farm units, it is assumed that comparable variations exist between farms in their respective areas.

used to select the communities, thus insuring a random selection. As such, these communities should represent the universe. The communities selected are outlined on the map on page 39.

Although 28,109 farms comprise the entire universe, the sample was drawn from a subdivision of the universe (the 13 PMA communities) which contained 2500 farm units. This means that the sample drawn represents .555 per cent of the entire universe, and 6.24 per cent of the farms in the thirteen randomly selected communities.

Twelve interviews were made in each of the thirteen communities. The twelve farm units were selected by using a table of random numbers; six alternates were selected for each community.

A schedule was prepared for use by the enumerator in the personal interviews with the farmers. (See Appendix A.) The schedule was designed to furnish the following information: (1) the total dollar value of output in 1950, including changes in inventory, and (2) the quantities of various resources employed during that year in producing that output.

In general, the schedule is self-explanatory. However, for certain items, some explanation concerning the derivation of their values is necessary. Under "crops" on Page 2 of the schedule, the respective values of all crops listed were computed by using the arithmetic mean of prices received by all farmers interviewed. This was necessary because some farmers could not place a value on certain crops; it also makes the output values comparable between farms. As a considerable price differential for spring wheat existed between Areas VI and VII vs. Areas III and IV, their respective average prices of \$1.95 and \$2.00 were used.

This differential in price can probably be explained by the difference in freight rates, Areas III and IV being in the eastern part of the state and closer to the terminal market. If the value of output is increased due to a favored geographical location, it should be reflected in the data. Average prices for all areas were used for other crops as no noticeable price differences existed. (See Appendix B for a listing of the average prices used).

The value of all pasture was computed by using a nine-month grazing season 1/, and a value of \$0.80 per Animal Unit Month (AUM). 2/ Then, total AUM's figured on the basis of the number of livestock each farmer carried during 1950 3/ times \$0.80 times 9 equals the total value of pasture on each farm. This method assumes pasture to be equally valuable throughout the area, and does not take into account the intensity of grazing. Rental rates may have been a better measure of this input but they were not available. Therefore, the somewhat arbitrary measurement of pasture value, as outlined above, was used. The farmer's estimate of the worth of his garden and potatoes was used in each case. On Page 3 of the schedule, a state average price for 1950 was used in calculating the

1/ A nine-month grazing season was considered the average length season for Areas III, IV, VI, and VII by the Bureau of Agricultural Economics, Montana State College.

2/ A figure of \$0.80 per AUM was calculated from a publication entitled: Basis for Developing Sliding Scale System for Grazing Fees, (mimeo), Soil Conservation Service, November 20, 1947.

3/ The Animal Unit conversion table used will be found in Appendix C.

value of milk and eggs. 1/ It was necessary to use state prices, as area prices were not available. Also, these are mostly home-consumed products, and many farmers did not have estimates of their value. On the basis of butterfat content, the price of milk used was \$0.0459 per quart. Eggs were figured at \$0.37 per dozen. These prices represent what eggs and milk would bring on the market, for if the farmer does not consume them, his alternative is to sell them. All livestock and other livestock products were assigned the value which each individual farmer placed on them. Averages were not used because they would have little significance. Livestock is too variable a product.

"Resource service input" on Page 5 under "Machinery and Equipment used on the Farm" is a figure which represents the cost of using a particular piece of equipment or machinery for the year 1950. A straight line depreciation factor was used to find the "resource service input" (annual cost of machinery). The replacement cost of a machine times the depreciation factor gives the annual cost of machinery. Factors used were as follows: tractors, .09; pickup truck, .10; other trucks, .087; drill, .043; combine, .11; baler, .125; field chopper, .094; and all other machinery and equipment, .056. 2/ For example, if the replacement cost of a tractor was \$3,000, then $\$3,000 \times .09 = \$270$, which is the cost

1/ Agricultural Prices, Bureau of Agricultural Economics, USDA, January 29, 1950 through December 29, 1950.

2/ These factors were supplied by the Agricultural Economics Department, Iowa State College, Ames, Iowa.

(resource service input) of using that tractor for 1950. All other items on the schedule are taken as the farmers' estimate of their value.

B. The Regression Analysis

As in the studies cited previously, Cobb-Douglas type functions, linear in the logarithms, were fitted to the data. Two functions have been computed: (1) a crop function, and (2) a livestock function. The crop function was derived from 151 observations, while only 111 were included in the livestock function. A discussion of the variables used for each function will follow.

The crop function is expressed as: $Y = \alpha X_1^a X_2^b X_3^c X_4^d X_5^e$

where: Y is the gross value of crop output including value of crop products plus miscellaneous receipts; X_1 is total crop acres; X_2 is total acres in wild hay and pasture; X_3 is the man-months of labor attributable to crop; X_4 is value of total machine services including custom work hired, fuel, annual cost of machinery plus repairs, annual cost of buildings for crops, and the annual cost of fences for crops; X_5 is total cash crop expenses including value of home grown seed sown, purchased seed, fertilizer, lime, and spray.

The method used in determining the annual cost of machinery has been previously outlined, (p. 43). The value of buildings was multiplied by .025 to find the annual cost of buildings. (Russell Shaw of Iowa State College provided this factor to use in finding the annual cost of buildings). Annual building cost was then multiplied by the proportion of labor used on crops to find the annual cost of buildings allocable to

crops. The remainder was charged to livestock.

The annual cost of fence was found by multiplying the total value of all fences on a farm by 6 per cent. This resultant figure was then multiplied by the ratio of crop acres to total acres and called the annual cost of fence to crops. The remainder of the cost was allocated to livestock. On farms with no livestock, the entire cost was allocated to crop. (An arbitrary figure of 6 per cent was provided by the Bureau of Agricultural Economics, Montana State College. This figure should also include interest on investment.)

The livestock function is expressed as: $Y_L = \alpha X_1^a X_2^b X_3^c X_4^d$
 where: Y_L is the value of total livestock output expressed as the value of non-breeding stock at the end of the year, plus the value of non-breeding stock sold, plus the value of livestock products used in the household, plus the value of breeding stock raised; X_1 is the value of total feed fed including home produced feed, plus feed purchased; X_2 is man-months of labor expended on livestock; X_3 is total livestock input expressed as the value of non-breeding stock at the beginning of the year, plus the value of non-breeding stock purchased, plus breeding herd depreciation; and X_4 is the value of other livestock input which includes the cost of buildings allocated to livestock, the cost of fences allocated to livestock, and other miscellaneous expenses consisting of veterinary expenses and livestock supplies.

Breeding stock raised includes beef cows, dairy cows, and ewes. The value of breeding stock raised was found by adding the number of breeding

stock sold and those on hand at the end of the year minus the sum of those purchased and on hand the first of the year times the average value of such breeding stock at the end of the year. This was done separately for each type of animal and their respective average values were used. The sum of these values constitutes the value of breeding stock raised. Using this procedure also eliminated the effect of a pure price increase in the value per head of all breeding stock.

Breeding herd depreciation was estimated by subtracting salvage value from the beginning value of the breeding herd and dividing by the expected (average) useful life. Differentials in prices and weights were included.

The functions were fitted statistically by means of the classical least squares regression where the sum of the squared residuals are minimized in the dependent variable. Values of the variables are taken from the survey data. Coefficients derived in the function are significant statistical estimates, their reliability being measured by their respective standard errors. The reliabilities of the functions are measured by the squared multiple correlation coefficients corrected for loss of degrees of freedom.

Multiple correlation coefficients as computed were found to be .8660 for the crop function and .9597 for the livestock function. These coefficients were both significant at the 1 per cent level of probability. This means the probability is less than 1 per cent that correlation as high as found could have arisen by chance if the true correlation coefficients were zero. The corrected coefficients of multiple determination

were found to be .7415 for the crop function and .9180 for the livestock function. These corrected coefficients show the percentage of variance in the total product associated with variance in the independent variables. More than 74 per cent of the variation in total crop output is associated with the measured inputs. The livestock function shows an exceptionally high corrected coefficient of multiple determination. These values correspond closely to those found in previous studies. ^{1/} Several factors can be responsible for the "unexplained" portion of the variation in total output. The study is for an average of farms and the "unexplained" portion could be attributed to only partial measurement of different techniques employed on the farms, no measure of the management input, and error in reporting the original data.

1. The Crop Function

Expressed in logarithms, the crop function was found to be:

$\log Y = .929689 + .224196 \log X_1 - .006735 X_2 + .065263 X_3 + .338398 X_4 + .468972 X_5$. The regression coefficients are the elasticities of output with respect to each factor of production. The coefficient for crop acres (X_1) is significant at the 5 per cent level of probability. Coefficients for pasture acres (X_2) and labor (X_3) were not significant. Coefficients for machine services (X_4) and cash crop expense (X_5) were significant at the .5 per cent level of probability. The elasticities show the average percentage change in output resulting from a one per cent change in input. If crop acres were increased by one per cent,

^{1/} See Part I.

total product on the average would increase by approximately .224 per cent. Diminishing marginal returns are indicated for each of the factors, since the elasticities in each case are less than one.

It will be impossible to include labor and pasture acres in the analysis. As they are statistically insignificant, no economic interpretation can be drawn for them either. There is no evidence of the effect of labor or pasture acres on output. If the input pasture acres was statistically significant, then increasing the use of this variable by one per cent would result in a decrease in output, as the coefficient is negative. As in previous studies, labor was measured in man-months and usually was not significant. Some other means for observing this input should perhaps be used. A fuller discussion of this problem will be dealt with in a following section (page 65).

Some indications of returns to scale are found when the elasticities of all factors are added together. If the sum of elasticities is greater, the same as, or less than one; then increasing, constant, and decreasing returns to scale, respectively, are indicated. In this case the sum of all elasticities was 1.09 which indicates a condition of increasing returns to scale. This result tends to coincide with increasing returns to scale which was indicated for a similar group of Canadian dry-land crop farms in Harries' study. ^{1/} For both cases, the assumption must be made that the sum of elasticities are significantly different from 1.0. The results would have been somewhat different for both studies had it been

^{1/} See pp. 31-33.

possible to measure management.

Marginal productivities were also computed for each of the factors. They are estimated at the geometric means of the variables and derived from the elasticities. Each respective marginal productivity is found by multiplying the elasticity of each factor by the ratio of the geometric mean of total output to the geometric mean of the respective factor. The marginal productivity indicates the expected average dollar return from the addition of one unit of each factor. The units added would be measured as: man-months of labor; acres of land; and dollars for all other factors. Marginal productivities as computed were found to be: $MP_{X_1} = 4.683859$; $MP_{X_2} = -.3468006$; $MP_{X_3} = 94.569041$; $MP_{X_4} = 1.645719$; and the $MP_{X_5} = 8.309473$. As pasture acres (X_2) and labor (X_3) did not have statistically significant elasticities, the marginal productivities for these factors are also insignificant and must be disregarded. Crop land (X_1) is measured in acres, therefore the interpretation must read that for every acre of land added, an average annual return of \$4.68 is forthcoming. Machine services (X_4) is measured as the actual cost of these services for the year 1950. Therefore, every dollar of increased cost here will yield an average annual return of approximately \$1.65, or a "net value of marginal product" of \$0.65. The highest marginal productivity is obtained from total cash crop expenses (X_4) where a return of \$8.31 could be expected for every dollar spent.

2. The Livestock Function

The regression equation for livestock expressed in logarithmic form

was found as $\log Y_L = .678881 + .287299 (\log X_1) - .017225 (\log X_2) + .582211 (\log X_3) + .104830 (\log X_4)$. All the elasticities are significant at the 1 per cent level of probability, except for labor (X_2) which is not significant. Increasing the livestock input (X_3) by 1 per cent would give on the average a .58 per cent increase in total output. Increasing this input gives a larger percentage increase in total product than any other variable.

Decreasing returns to scale are indicated for the livestock enterprise as the sum of the elasticities is less than 1.0 (0.9571). This figure is, however, very close to 1.0 which would indicate constant returns.

Marginal productivities were found to be: $MP_{X_1} = .928214$; $MP_{X_2} = -16.06157$; $MP_{X_3} = 1.5771147$; and $MP_{X_4} = 4.566624$. Again the marginal productivity of labor (X_2) must be disregarded as it is statistically insignificant. For total feed fed (X_1), every dollar invested here will yield an average return of approximately 93 cents. The results indicate that the greatest return can be expected from other livestock input (X_4) which includes the cost of buildings and fence to livestock and veterinary expense. According to the marginal productivity, a return of \$4.57 is forthcoming for every dollar spent. This variable includes several inputs which makes economic interpretation difficult.

C. Implications of the Study

1. General Implications

Before proceeding with the analysis, it is well to point out again that this is primarily a dry-land crop study. Measured at the geometric

means, the gross returns to livestock made up less than one-fourth of total receipts. The crop function can be considered as closely approximating an aggregate function.

Increasing returns to scale was found for the crop function. This would indicate if the summation of elasticities is significantly greater than one, that the average of farmers are operating in a theoretically uneconomic range. Such a conclusion corresponds with the hypothesis that wheat farms should be expanded in size. By so doing, the average farmer would be increasing his net farm income.

This same point is illustrated when the marginal productivity of crop land is examined. A return of \$4.68 is forthcoming for every acre of crop land added on the average farm. From this, the conclusion can be drawn that it would be profitable for the average farmer to increase crop acres if the prices of all inputs vs. output remain the same, or increase or decrease in the same proportion. If the return of \$4.68 is capitalized at 5 per cent, then the value of land should have been \$93.60 an acre in 1950. According to the 1950 Census of Agriculture, the average of all land and buildings for the counties in which samples were drawn was \$20.18. ^{1/} A simple average of all land and buildings, as estimated by the farmers in the study, was found to be \$40 an acre. It was impossible to derive a figure for crop land alone, as such information is unavailable. However, a figure of \$40 an acre may be close to the value

^{1/} 1950 Census of Agriculture, Preliminary, Series AC 50-1, "Farms, Farm Characteristics, Farm Products", Bureau of the Census.

of crop land alone. Although the figure includes pasture land, farm buildings and the house are also included, the extra value of which may compensate for the lower value of pasture land. At any rate, if \$50 an acre were used for crop land, a difference of \$43.60 an acre exists. This means, on the basis of 1950 prices and yields, land is considerably undervalued, or farmers are not using enough crop land. Alternatively, the returns to land were exceptionally high and increasing crop acres would be a profitable means of expanding the enterprise.

The input of machine services is measured by the actual cost of these services. Several separate factors (custom work hired, fuel, machinery repairs, and the annual cost of machinery, buildings, and fence are included in this category, which makes economic interpretation difficult. A return of approximately \$1.65 is indicated when the cost of these services are increased by \$1, giving a net marginal return of \$0.65. An increased use of these factors should increase net farm income and bring about a more efficient allocation of resources. However, on the basis of the statistical function, it is impossible to say which factor or in what proportion they should be increased, for the effect each factor has on total output is not known. There is only the indication that a more efficient use of these resources could be brought about.

Total cash crop expenses was found to have the highest statistically significant marginal productivity. A return of approximately \$8.31 is indicated for every dollar spent. This variable includes mainly home grown seed sown, purchased seed, and spray. Spraying wheat to control weeds is generally recognized as a profitable practice. Experimental

evidence has shown an average return of \$7.53 per dollar spent on spray.^{1/} The extremely high marginal productivity of this group of resources seems to bear this out, indicating that it would be profitable for most farmers to spray for weeds.

Under a position of equilibrium with competitive conditions existing, the value of the marginal productivities should all approximate one if output is measured by gross receipts, and if inputs are measured as a flow of resources and not the stocks of resources from which the flow is derived. Under such conditions, a dollar would be received for every dollar spent and the "net value of the marginal product" would be zero. It would then be impossible to increase net farm income in the "short run" sense. In practice, it is extremely doubtful if such a condition can be attained, but all the marginal productivities should be as near equal as possible to maximize net farm income. All variables must be measured in the same manner for this condition to hold. Although all variables are not measured in the same way, it can be seen that much is to be desired by way of obtaining a more efficient allocation of resources.

According to the sum of the elasticities for the livestock function, this enterprise is operating under constant or slightly decreasing returns to scale. When compared with the crop function, the size of this enterprise is closer to the economically relevant range (the range between the point of inflection and the highest point on the total product curve).

^{1/} Unpublished Article by Myrick, D. C. and Warden, R. L., It Pays to Spray -- At the Right Time and at the Right Rate, Bureau of Agricultural Economics, Montana State College.

Due to the conditions existing in the area studied, it is doubtful if the livestock enterprise can be greatly expanded. Many times water for stock is unavailable, grazing land may not be available, also the cost of fencing unused grazing land where no fences exist might not pay for itself in a short enough period. As the category in which fences are included shows a high marginal productivity, further investigation is needed here. Livestock is mostly a supplemental enterprise and exists apart from the dry-land operation. Most wheat farmers keep livestock only as a hedge against price and weather uncertainty. The goal for the average farmer would appear to be using his present livestock resources most efficiently by equating their marginal productivities.

The marginal productivity for total feed fed was found to be .928214. This is close to 1 which indicates an efficient use of this factor. Returns to the livestock input indicate a return of approximately \$1.58 for each dollar invested. Such a figure indicates it would be profitable to expand livestock numbers. However, due to the above mentioned conditions, this may be impractical. A return of \$4.57 was indicated for every dollar invested in other livestock input, which includes the cost of fences and buildings to livestock, and other small miscellaneous livestock expense. Fences and especially buildings for livestock are limited on Montana dry-land crop farms. If the livestock enterprise is to be made more profitable, then for the average of farms, additional money available for the livestock enterprise should be spent for this factor first. For the livestock function, as well as the crop function, considerable divergence exists between the marginal productivities of the variables. Therefore,

on the basis of the marginal productivities, it is generally indicated that as more money is spent for variables with high productivities, they should be reduced and others with low values should be raised, bringing about a more efficient allocation of resources. It must be remembered that marginal productivities are derived at the geometric means, and are, therefore, applicable mainly for the area as a whole.

On the basis of the marginal productivities, the results seem to indicate: (1) use less feed; (2) use more livestock; and (3) use more other livestock input. Labor for both functions and pasture in the crop function are statistically insignificant, but indications are that relatively too much of these inputs are used. On the basis of the foregoing observations, it might be concluded that grazing intensity should be increased on the present pasture acreage, and livestock facilities should be improved.

2. Special Implications

The results of this study have implications of varying degree for three groups or fields of study: (1) farmers; (2) investigators in agricultural sciences; and (3) agricultural policy. They will be treated in the order listed.

An individual farmer in the area studied can use the data only insofar as he approximates the average farmer. Obviously, this is a serious limitation from the standpoint of the individual farm operator. The marginal productivities are calculated at the geometric mean which means they are evaluated at a specific point on the total product curve. As most farmers do not use the same technique (production function) as developed for the

average of all farms, then little can be said for the use of the study in helping him make production decisions. Even if the marginal productivities were valid for the individual farmer, such limitations as the indivisibility of resources, the effects of capital rationing, and social restrictions might prohibit the farmer from making the desired adjustments. These same limitations hold in analyses regarding the implications for agricultural policy and research in agricultural sciences.

Investigators in agricultural sciences may use the study as a basis for further research in the production field. Certain mistakes and weaknesses of this study should be pointed out in order that other researchers may not make the same errors. It is through this process that the science in any field grows and develops. The implications of the study for this group will be discussed in a following section on "Suggestions for Further Research."

Workers in agricultural policy should have much to gain from this type of analysis. Policy formation deals more with the aggregate situation, being the situation for which a study such as this is most adapted. Maximizing welfare for the community as a whole is the norm of welfare economics. Following Reder, welfare is defined in terms of a welfare indicator, with the indicator defined as follows: "welfare increases (decreases) whenever one or more individuals become more (less) satisfied without any other individuals becoming less (more) satisfied."^{1/}

^{1/} Reder, Melvin Warren, Studies in the Theory of Welfare Economics, New York, Columbia University Press, 1951, pp. 14-15.

The same idea of welfare should be incorporated into agricultural policy. Following, the efficiency with which resources are combined becomes an important consideration. In our economy the price system is supposed to do the job of rationing scarce resources. It is known, however, that due to elements of monopoly and the immobility of resources, the movement of resources into fields where they have their greatest comparative advantage (defined in terms of maximum economic product for the society as a whole) does not always take place. People do not have perfect knowledge; the costs of transferring resources are often too great; the risk and uncertainty of change is a factor; and also human abilities are often inflexible.

In examining resource combinations and allocation we have a two-fold objective; i.e., obtaining the maximum return for the farmer and the maximum return for society. In these terms, both the farmer and society are interested in production efficiency. The trouble arises in the fact that the objectives of the farmer and society may conflict. Among other things, the farmer may regard leisure as being more important than maximum production. Intangible values become evident through variabilities in human nature, and we find people who do not wish to "maximize". However, society as a whole does benefit from economic progress, and more efficient use of resources is one of the means of attaining that end.

In light of threatening world conflict, our nation may have to maximize the real value of goods and services from our existing resources to save itself from disaster. Every resource would need to be placed in a position where it held the greatest comparative advantage. This would

apply to all the factors of production, including land, labor, management, and all forms of capital and capital goods. If the physical production functions were known, then resource use could be shifted more effectively. Resource shifts could be made in time of emergency, which cannot take place under normal conditions when economic and social institutions are more rigid. This is not to say that resource movement does not take place under normal conditions; it only occurs more slowly. In the interest of economic progress, these changes should take place more rapidly than they do. The point is that a measure of the efficiency of resource use is needed as a basic starting point in determining where, and in what combinations, resources should be combined in the production process. Once this has been established, policy formation and the action of the entrepreneur should both be more consistent with the goals of economic efficiency and economic progress.

Policy implications with respect to economic efficiency are indicated by this study. Increasing returns to scale were found for the average of farms studied. Certain legislative measures to promote increased farm size is indicated as desirable. This could take the form; e.g., of loans for expansion and fewer credit restrictions in production. The marginal productivities could be used as bases for credit; e.g., extend credit to buy chemical spray and not livestock feed. The danger lies in the fact that credit policies which are too liberal would promote inflation and instability. It must be remembered that this is a high risk area and any policy recommendations must be tempered with this consideration.

Whenever possible, to approach a condition of "balanced resource

use", education should be used to bring about the more intensive use of items which show high marginal productivities. As indicated by this study; crop acres, machinery, buildings, spray, and livestock inputs should be used more extensively in the area as a whole. Subsidies should be used only as an incentive for the farmer to effect a better balance of resource use when such a change is profitable for the farmer as well as society. In some cases, certain internal and external factors may keep the farmer in his present condition.

PART III. CONCLUSIONS

A. Limitations of the Study

However useful the production function type of analysis may be in examining the problem of "balanced farming", its limitations need to be delineated. Any conclusions drawn from this study must necessarily be subject to the following limitations.

The problem of grouping resources into homogeneous categories is complex and difficult. Both the size of the universe and the degree of diversification of farming practices are inversely related to the homogeneity in classification of resources that can be attained. Generally, climate, soils, market, and institutional factors become more diverse as the geographical universe expands. Although the universe of farms in this study encompasses considerable area, some compensation is obtained by defining the universe to contain primarily dryland wheat farms. By so doing, variation in farming practices is reduced.

Certain factors are used jointly in the production process and are complementary to each other. When this relationship exists, the resource efficiency measurement of a particular resource taken separately has little statistical significance because of high inter-correlation. If this complementarity is known "a priori", such resources should be combined into the same group so as to promote statistical reliability. When such relationships are suspected but not known, it would be profitable to make a preliminary analyses on a small sample taken from the entire group to determine the degree of correlation between factors. If a high degree

of correlation exists, they should be combined into one independent variable.

Care must be exercised in drawing causal relationship inferences from the results. The statistical technique is not designed to establish causal relationship, but to measure the degree of relationship. Therefore, conclusions drawn from the study must be based on economic theory as well as the statistical results.

A further limitation is that this analysis is not strictly a physical input-output relationship. Output and most inputs are measured in terms of dollars, thereby reducing the relationship to one of dollar values. At best, the analysis applies only to the "short run" and will hold from year to year only if prices of input and output increase (decrease) proportionately, or remain the same.

In this analysis, the dynamic aspects of our economic system are not considered. Therefore, such aspects as flexibility, risk, and uncertainty in production are not considered. Incorporating these items into the analysis would be a sizeable task, but is a problem worthy of investigation.

The analysis applies only to the average of farms, and therefore does not necessarily coincide with any one farm. The production function derived is an average of the functions for each farm. As the deviation from the average function increases, the economic interpretation that can be made becomes more limited. Marginal productivities computed are averages of marginal productivities of resources and will not necessarily coincide with any particular farm. Although every effort may be made to pick homogeneous farms, a multitude of resource combinations will exist because

of differences in management abilities. Comparisons of the statistical results have increased meaning when individual production factors are compared between farm groups rather than within a single group. Ideally, production function techniques are useful in inter-regional analysis whereby different types of agriculture can be examined. Also, efficiency in agriculture could be compared with efficiency in industry.

Management has not been included explicitly in the categories of inputs. This productive factor does not lend itself to objective measurement. Some of the management input is probably included in some of the other input categories, but how much is not known. If it were possible to measure management explicitly, it does not necessarily follow that the sum of elasticities would have been greater; the individual elasticities may have been smaller. ^{1/} As yet, management remains an intangible, the results of which can be observed but not easily measured. This limitation is not one that plagues production function analysis alone, but all other types of production economics studies as well.

Finally, the accuracy and adequacy of the analysis must be directly dependent upon the original data. The author was also the enumerator in gathering data for this study. Every effort was made to gather unbiased information. However, from observation, many of the farmers' estimates of resources used are rough approximations, at best. In most cases, this

^{1/} Heady, Earl O., "Production Functions from a Random Sample of Farms," Journal of Farm Economics, Vol. XXVIII, No. 4, November, 1946, p. 997.

was not deliberate; the frailties of human memory are responsible. It can only be hoped that the over-estimates will balance out the under-estimates. This limitation is common to all survey studies.

B. Suggestions for Further Research

Production functions as developed in this study are not physical input-output relationships, but rather capital input-output relationships. Current prices in 1950 were used to value inputs and outputs, except for the inputs labor and land. When the variables are measured in this way, the analysis is restricted largely to 1950.

The development of a strictly physical input-output relationship has many desirable implications. Relationships between the variables should hold over a longer time span (until new techniques are used). Techniques of production supposedly do not change as rapidly as price ratios. Then the desired prices of resources and products can be used in the analysis to determine the relevant economic solution of optimum resource combination. The trouble arises in trying to reduce diverse factors and output to a measurable common denominator. Further research should be conducted on this problem.

This study can be criticized somewhat for the way in which certain inputs were measured. When measuring resources in whatever terms, it would be desirable to measure the flow of resources and not the source from which the flow is derived, for it is actually the flow which affects production and not the stock of resources. In many cases, the two are highly correlated, but the value of the marginal productivity relates

only to the flow. At any rate, a consistent measure should be used to allow easier comparison between the variables. In this study, land and labor were measured in acres and man-months, respectively, while other inputs were measured in dollar terms. Land is measured as the stock of resources in physical terms. Labor is a flow of resources and measured in physical terms. Ease of comparison and perhaps increased reliability could be attained if all resources had been measured as the flow in dollar terms.

Land and buildings are usually included as one input. In this study they were measured separately in order that the costs of these factors might be divided between the crop and livestock enterprises. Something can be said for including them in one category and then splitting the costs. Land and buildings are both fixed resources in the "short-run" and the value of land tends to be made up in part by the value of the buildings. Although market value of the farm, as estimated by the farmer, is not always too accurate, it seems a better measure than acres because the value will more likely reflect variations in productivity between farms. The cost of this combined factor can then be found by multiplying market value by an alternative rate of interest which is the opportunity cost of renting the land and buildings. This cost could then be divided between the livestock and crop enterprises by using the ratio of crop acres to total acres to find the cost to the crop enterprise. The residual cost would be allocated to livestock. This would be an arbitrary division,

but it may be better than the method used. Other alternative methods should be explored; e.g., a physical productivity factor for adjusting variations in land.

With the exception of the Tintner and Tintner and Brownlee studies, labor has been an insignificant variable in all past production function studies, including the present one. In these studies, labor was measured in man-months. In this study it was hoped that the error in measuring labor would be reduced by asking the amount of time in months actually spent in production. Apparently this did not alleviate the situation. Labor is a difficult item to measure accurately as the value of labor has considerable variation between farms. An implicit assumption involved in production function analysis is homogeneity of factors between farms. Labor is one of the least homogeneous of factors. Although difficulties arise, it might be well to measure labor in dollar terms. The wage paid to "steady" hired labor is generally a fair index of the productivity of that labor. Value of the farm operators' labor could be found by asking the wage he would earn if working for someone else. In essence, this is the farmer's opportunity cost. The danger lies in that this may also reflect a return for the farmer's management. In the present and previous studies, the difficulty encountered with labor must lie in its measurement. A separate study dealing with this problem could be conducted.

The annual cost of using machinery was found by multiplying the replacement cost by a depreciation factor which accounts for depreciation,

repairs and maintenance, and interest on investment. It might be well to examine the separate components of the cost of machinery and use separate calculations for each. The sum would be total annual machinery cost. Such a method would complicate figuring the cost of this variable, but it should be more accurate.

It would be possible to test further hypotheses with the use of the data gathered in this study. This would involve setting up more regression equations. Using some arbitrary classification the farms could be divided into "small" vs. "large" farms to see if any significant differences in returns to scale exist, and also to examine further the marginal productivities of input relative to "balanced resource use." Other groupings could include: spring wheat vs. winter wheat; wheat with no livestock; and separate functions for the four Montana Type of Farm Areas included in the entire study. An aggregate function which includes both the livestock and crop enterprises is being computed by Iowa State College, but is at present unavailable.

Factors which show high marginal productivities may be worthy of further investigation to test the profitability of increasing their use. A study of land values in connection with existing rental rates could yield useful information dealing with the division of costs and returns between the landlord and tenant.

Enough information is available to develop an alternative approach to "balanced resource use" by using the conventional budget method of analysis. The results of such an analysis could be compared with the results found in this study. If they showed comparable results, the

validity of this study as well as the budget method would be enhanced considerably.

This type of study is especially useful in comparing resource efficiency between agricultural regions. Such a study is being conducted at Iowa State College using the functions developed in this study, together with studies from several other regions.

Use of the production function in analyzing farm data is quite new. Extensive research needs to be carried on to determine its actual validity and usefulness in examining "balanced farming." It is certain that this type of analysis leaves much to be desired, and refinements in the methodology are needed. It does, however, open new paths into the field of production economics.

A P P E N D I X

APPENDIX A

RESOURCE PRODUCTIVITY ON DRYLAND CROP FARMS, 1950

MONTANA STATE COLLEGE

A. Identification:

Name _____ Farm number _____
 Address _____ County _____
 _____ Type of farm area _____

B. Size and Tenure:

1. Total Acres:	Owned	Rented	Total
Dry			
Irrigated			
Total			

Crop Acres:	Owned	Rented	Total
Dry			
Irrigated			
Total			

2. For land rented:

Cash of \$ _____ per Acre or \$ _____ total

Share to landlord of _____ of wheat,

_____ of _____, _____ of _____.

3. For land owned: the customary lease would give you \$ _____

cash or _____ of wheat, _____ of _____, _____ of

_____, _____ of _____.

(schedule page 1)

C. Crops: Organization, Production, Disposition

Crop	Unit	Acres	Produced		D I S P O S I T I O N								I n v e n t o r y			
			Qty.	Val.	Idld.		Sold		Bought		Used		1/1/50		1/1/51	
					Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
W. wheat																
S. wheat																
barley																
potatoes																
garden																
waste																
TOTAL																

(schedule page 2)

D. Livestock Inventory

Kind	1/1/50 Inventory		Purchased		Sold		1/1/51 Inv.		Used in Household		Land-lord	House-hold
	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
	1	2	3	4	5	6	7	8	9	10	11	12
Beef cows												
2 yr. olds												
yearlings												
PRODUCTS:												
wool												
milk												
eggs												

(schedule page 3)

Item	Value	Rate	Operator	Landlord
Temporary labor off farm days				
Tractor work for others				
Combining hours				
Spraying hours				
Baling hours				
Other machine work days				
Benefit Payments				
Refunds (gas tax, etc.)				
Insurance Rec'd.				
Cash or share rent received for land or pasture				
Cash rent for equip. received stock, etc.				
Other Misc. income				
TOTAL				

Farm Expenses

Item	Unit	Amount	Total	Amount Paid by Operator: Landlord	
Fertilizer Analysis					
Spray materials	xxx	xxxx			
Custom work hired					
Combining	days				
Spraying	days				
Baling	days				
Other	days				
Machinery Repairs (not incl. tractor or truck)	xxx	xxx			
Purchased seed					
Tractor truck & other engines;					
gasoline	xxx	xxx			
distillate	xxx	xxx			
repairs, tires, overhauls	xxx	xxx			
licenses & insurance	xxx	xxx			
Car Expense (farm share)					
Purchased feed:					
cottonseed meal	Cwt.				
linseed meal	Cwt.				
soybean meal	Cwt.				
other protein	Cwt.				
dairy feed	Cwt.				
beef feed	Cwt.				
hog feed	Cwt.				
(schedule page 4)					

Farm Expenses (continued)

Item	Unit	Amount	Total	Amount paid by Operator: Landlord	
laying mash	Cwt.				
chick mash	Cwt.				
minerals & salt	Cwt.				
other mixed feed	Cwt.				
Veterinary, medicine, etc.	xxx	xxx			
Breeding fees	xxx	xxx			
Registration fees	xxx	xxx			
Dairy & Beef supplies	xxx	xxx			
Hog supplies	xxx	xxx			
Poultry supplies	xxx	xxx			
Hauling	xxx	xxx			
Fencing					
Bldg. Repairs (materials)					
(special services)					
Electric bill (farm share)	xxx	xxx			
Telephone bill (farm share)	xxx	xxx			
Taxes (property) personal	xxx	xxx			
real estate	xxx	xxx			
Interest paid	xxx	xxx			
Insurance paid (crop)					
other					
Cash rent paid out					
Machine depreciation, Bldg.	not to be enumerated here				
depreciation, Fence deprec.					
Cash labor paid					
TOTAL					

Machinery and Equipment Used on Farm
(excluding custom machine work)

Item	No.	Beginning of year		Was this machine sold or traded during year's operation date	Re- source service input \$ **
		Market Value \$	Replacement value if new \$		
Tractor size * age yrs.					
Tractor size age yrs.					
Tractor size age yrs.					
Tractor size age yrs.					
Pick-up truck age yrs.					
Other truck age yrs.					
Car Model yr.					
Farm share %					
Drill age yr.					
Combine or binder: age yrs.					

(schedule page 5)

Machinery and Equipment (continued)

Item	Beginning of yr.		Was this machine sold or traded during yr.'s operation	Resource service input \$
	No.	Market Value	Replace-ment val. if new \$	
Baler: age yrs.				
Field Chopper age yrs.				
All other machinery & equip. xxx				
TOTAL				

* Size: 1-plow; 2-plow; 3-plow; etc.

**not to be enumerated

Were all of these machines supplied by the operator

What was the value of all new machinery purchased during the yr. \$ _____

value of all machinery sold or traded during the year \$ _____.

LABOR

Item	No.	Man-equiv. Months	Rate		value: \$
			with: board	without board	
Operator					
Operator's wife					
Operator's children boys ages _____					
girls ages _____					
Other family					
Hired labor-day labor _____ days		*	/day	/day	
Monthly labor			/mo.	/mo.	
TOTAL					

*must be converted from days to months.

Was any of the family labor paid \$ _____. Approximately what per cent of the total labor employed was used for crops ____%. How many months did operator spend off the farm _____ total months.

REAL ESTATE:

Value of all land, buildings and house \$ _____.

Value of all buildings \$ _____.

Value of all fences \$ _____.

Amount of fence _____ (miles or rods)

(schedule page 6)

What was the net charge in purchased feed inventory / \$ _____ or - \$ _____.

What was the net charge in fertilizer on hand / \$ _____ or - \$ _____.

What was the value of land and building sales \$ _____. Purchases \$ _____ during 1950.

Non. Farm Assets

What is the value of other property and assets (aside from household).

Which you own: \$ _____ cash or in bank; \$ _____ in bonds; \$ _____ loan value of life insurance; \$ _____ in annuity or other retirement plan (not included above); \$ _____ of off farm property, stocks, etc.

Total Liabilities

What is the value of any debts which you have: \$ _____ real estate mortgage; \$ _____ chattel or other mortgage; \$ _____ wheat storage loan; \$ _____ notes; \$ _____ unpaid bills (hospital, store, etc.): \$ _____ other. What was the income from off farm investments \$ _____. What was the value of all other off farm income \$ _____.

(schedule page 7)

APPENDIX B

AVERAGE OF PRICES RECEIVED BY ALL FARMERS INTERVIEWED*

<u>Product</u>	<u>Unit</u>	<u>Average Prices</u>
Winter Wheat	Bu.	\$ 1.91
Spring Wheat	Bu.	2.00
Barley	Bu.	.99
Oats		
Grain	Bu.	.68
Hay	T.	21.38
Crested Wheat Grass		
Seed	Lb.	.18
Hay	T.	18.46
Pasture	A.	2.38
Native Hay	T.	19.02
Mustard Seed	Lb.	.13
Flax Seed	Bu.	3.30
Alfalfa		
Hay	T.	24.93
Seed	Bu.	27.72
Rye Hay	T.	22.50
Wheat Hay	T.	26.95
Wheat Straw	T.	10.00
Sweet Clover Hay	T.	20.00
Corn Stover	T.	13.71
Millet	T.	20.00
Mixed Tame Hay	T.	19.83

*Winter Wheat was found only in Areas VI and VII. The average price of spring wheat was \$1.95 in Areas VI and VII, while it averaged \$2.04 in Areas III and IV. These respective prices were used for the respective areas.

APPENDIX C :

ANIMAL UNIT CONVERSION TABLE*

<u>One</u>	<u>Equals</u>
cow (with or without pre-weaned calf)	1 A.U.
bull	1 "
2-yr. steer or heifer	1 "
1-yr. steer or heifer	3/4 "
calf (after weaning)	1/2 "
ewe (with or without pre-weaned lambs)	1/5 "
ram	1/5 "
lamb (after weaning)	1/10 "
sow (with or without pre-weaned pigs)	1/5 "
boar	1/5 "
pig or shoat (after weaning)	1/10 "
horse	1 "
2-yr. colt	3/4 "
1-yr. colt	1/2 "
colt under 1 year	1/4 "

*Cited from lecture notes in the Farm Organization class of T. R. Hodges, Division of Agricultural Economics, University of California, Davis, California, September, 1949 - January, 1950, and modified by data in Mont. Bul. 459, re. Procedure for Land Reclassification, p. 24.

APPENDIX D

Crop Function

In general form, the crop function is: $Y = X_1^a X_2^b X_3^c X_4^d X_5^e$. Expressed in logarithms, the crop function as computed is: $\log Y = .929689 + .224196 (\log X_1) - .006735 (\log X_2) + .065263 (\log X_3) + .338398 (\log X_4) + .468972 (\log X_5)$.

The "t" test was used to test the significance of the variables; the results appear as follows:

$t(a) = 1.94^* \underline{1/}$	Degrees of Freedom = $151 - 6 = 145$
$t(b) = 0.37 \underline{1/}$	$t .05 = 1.656 \underline{2/}$
$t(c) = 0.95 \underline{1/}$	$t .025 = 1.976 \underline{2/}$
$t(d) = 3.18^{**} \underline{1/}$	$t .005 = 2.609 \underline{2/}$
$t(e) = 4.59^{**} \underline{1/}$	$R = .866095 \quad R^2 = .7415$

*significant at 5% level

**significant at .5% level

1/ derived from observations

2/ derived from the table

The geometric means of the variables are:

$$X_1 = 774.61$$

$$X_4 = 3,327.6$$

$$X_2 = 314.28$$

$$X_5 = 913.34$$

$$X_3 = 11.168$$

$$Y = 16,183$$

Correlation coefficients of the logs of the variables are:

$$\begin{aligned}
 r_{Y1} &= .818349 & r_{12} &= .062976 & r_{23} &= .252653 & r_{34} &= .644216 & r_{45} &= .773853 \\
 r_{Y2} &= .118641 & r_{13} &= .588322 & r_{24} &= .265324 & r_{35} &= .574280 \\
 r_{Y3} &= .577040 & r_{14} &= .796859 & r_{25} &= .100011 \\
 r_{Y4} &= .775306 & r_{15} &= .894263 \\
 r_{Y5} &= .836579
 \end{aligned}$$

Livestock Function

In general form, the livestock function is: $Y_L = X_1^a X_2^b X_3^c X_4^d$.

Expressed in logarithms, the livestock function as computed is: $\log Y_L = .678881 + .287299 (\log X_1) - .017225 (\log X_2) + .582211 (\log X_3) + .104830 (\log X_4)$

The "t" test was used to test the significance of the variables; the results appear as follows:

$$\begin{aligned}
 t(a) &= 5.67^{**} \underline{1/} & t_{.05} &= 1.983 \underline{2/} \\
 t(b) &= 0.44 \underline{1/} & t_{.01} &= 2.624 \underline{2/} \\
 t(c) &= 13.33^{**} \underline{1/} & \text{Degrees of Freedom} &= 111-5 = 106 \\
 t(d) &= 2.63^{**} \underline{1/} & R &= .959700 & \bar{R}^2 &= .918
 \end{aligned}$$

^{**} significant at the 1% level

1/ derived from observations

2/ derived from the table

The geometric means of the variables are:

$$X_1 = 1,657.5$$

$$X_4 = 122.93$$

$$X_2 = 5.7430$$

$$Y = 5,355.1$$

$$X_3 = 1,976.9$$

Correlation coefficients of the logs of the variables are:

$$\begin{array}{llll} r_{Y1} = .869816 & r_{12} = .584255 & r_{23} = .618700 & r_{34} = .656774 \\ r_{Y2} = .613536 & r_{13} = .803584 & r_{24} = .587800 & \\ r_{Y3} = .936489 & r_{14} = .701063 & & \\ r_{Y4} = .721841 & & & \end{array}$$

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