



Delineating firms sensitive to shifts between wheat and range forage in the northern Great Plains  
by Dwight M Blood

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

The purpose of this study as stated in Part II is to investigate a methodology for delineating firms which are sensitive to shifts between wheat and range forage production.

Part I lays the groundwork for the study by presenting a general picture of the shifting situation in the Northern Plains as it has existed in the past, and the general situation which operators of units sensitive to shifts are faced with today. Some of the implications of shifting situations are noted.

Part II defines the specific research problem and establishes the economic criteria for determining optimum wheat-range forage production patterns in dry land areas. The factors relevant to achieving an estimate of the economic model are then described. From this framework, the hypothesis of the study is derived.

Part III carries the empirical tests of this hypothesis. Use is made of linear discriminant analysis and multiple regression techniques in an attempt to carry out the purpose of the study and form a basis for inferences concerning the analysis.

Part IV summarizes the positive accomplishments and sets forth suggestions for further research. Success in the development of the discriminant function suggests still further applications of this technique. Moreover, it may have succeeded in isolating a set of conditions permitting an increase in research productivity.

DELINEATING FIRMS SENSITIVE TO SHIFTS  
BETWEEN WHEAT AND RANGE FORAGE  
IN THE NORTHERN GREAT PLAINS

by

DWIGHT M. BLOOD

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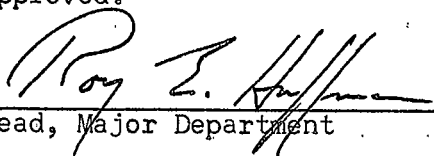
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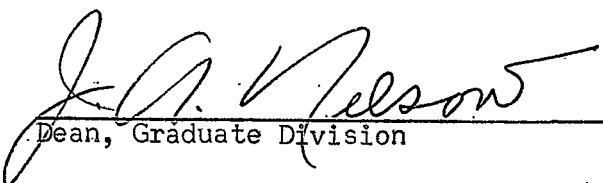
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Montana State College

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Bozeman, Montana  
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## ACKNOWLEDGMENTS

A special debt of gratitude is due Professors C. B. Baker and E. H. Ward for countless hours of guidance and direction spent in developing and completing this thesis. Professor C. B. Brotherton contributed criticisms strengthening the text in several places.

The circulation and reference librarians of the Montana State College library were most helpful in locating obscure government publications and other research material.

To my wife, Velna, goes my special thanks for patient endurance and countless retypings of the manuscript.

Professor J. A. Hopkin of the University of Wyoming indirectly caused the writing of this thesis since his example and encouragement furnished the incentive for undertaking graduate study in Agricultural Economics.

Finally, many other staff members and my graduate colleagues deserve recognition for help freely given in numerous ways.

## ABSTRACT

The purpose of this study as stated in Part II is to investigate a methodology for delineating farms which are sensitive to shifts between wheat and range forage production.

Part I lays the groundwork for the study by presenting a general picture of the shifting situation in the Northern Plains as it has existed in the past, and the general situation which operators of units sensitive to shifts are faced with today. Some of the implications of shifting situations are noted.

Part II defines the specific research problem and establishes the economic criteria for determining optimum wheat-range forage production patterns in dry land areas. The factors relevant to achieving an estimate of the economic model are then described. From this framework, the hypothesis of the study is derived.

Part III carries the empirical tests of this hypothesis. Use is made of linear discriminant analysis and multiple regression techniques in an attempt to carry out the purpose of the study and form a basis for inferences concerning the analysis.

Part IV summarizes the positive accomplishments and sets forth suggestions for further research. Success in the development of the discriminant function suggests still further applications of this technique. Moreover, it may have succeeded in isolating a set of conditions permitting an increase in research productivity.

## PART I.

## INTRODUCTION

If it were necessary to make a choice of one word which would best describe the Northern Plains, that one word would undoubtedly be "uncertain". Endowed with an unstable and widely varying weather foundation upon which the agricultural economy of the region must be established, the already existing problems related to price variations are magnified by extreme variations in production. The intricate facets of uncertainty are great obstacles in analyzing potential shifts. Encompassing a physical area of approximately 300,000 square miles, the Northern Plains contains roughly a tenth of the total land area of the United States. <sup>1/</sup> It is bounded on the east by the 98th meridian, and on the west by the Rocky Mountains. The Canadian border marks the upper boundary on the north, while the southern extremity is represented roughly by the 43rd parallel. Included within these boundaries is ". . . the western three-fourths of North Dakota, South Dakota, and Nebraska, the eastern two-thirds of Montana, the eastern one-third of Wyoming, and the northeastern one-tenth of Colorado . . ." <sup>2/</sup>

The region is one of extremes, making the use of "averages" deceptive. The climate of the Plains ranges from conditions approximating those of the humid Midwest at the 98th meridian to semiaridity over most of the region.

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<sup>1/</sup> George A. Rogler and Leon C. Hurtt, "Where Elbowroom is Ample", Grass, U.S. Dept. of Agriculture Yearbook, 1948, p. 477.

<sup>2/</sup> Loc. cit.

The 98th meridian serves as the dividing line since its annual precipitation averages approximately 20 inches, which is the minimum for successful production of most humid area crops. This is reduced to approximately 10 inches toward the western extremes.

The significant aspect of the moisture supply in the Plains lies not in its total variation, but in the fact that it hovers so closely around the critical margin for plant survival, where a small adverse variation can spell disaster.

The topography of the Plains ranges from a gently rolling surface over most of the eastern portions to the rough and broken areas of the west.

The changing aspects of climate and natural factors are reflected by continually changing patterns of land use. The one extreme is represented by areas in which wheat production strongly predominates; the other by an almost complete range forage and livestock producing economy. In a rather indistinct area somewhere between these two extremes can be noted areas in which wheat and livestock ranches are coexistent, or where wheat and livestock are both produced on the same ranch.

Generally speaking, these two extremes represent the two principal generalized types of farming in the region. "Islands" of irrigated farming complete the picture. These enhance the stability of the region and complement the dry land areas in important ways.

#### The Wheat and Small Grains Area

The 98th meridian is the scene of transition between the humid Midwest and the semiarid wheat producing area of the Northern Plains. This

is the margin of transference of wheat to a more intensive type of agriculture. The transition is first evident in rainfall and other climatological changes, which is in turn reflected by the changing physical characteristics of the land itself.

The transition is finally reflected by changing agricultural production patterns. Crop production predominates in this area, with a tendency toward specialization in the production of wheat.

#### The Range Livestock Area.

To the south and west of the major wheat producing areas, as rainfall diminishes and as the terrain becomes steeper and rockier, the relative advantages for wheat production diminish. At the same time the relative advantages for cattle production increase. At the area of transition between these two major types of agricultural production lies the margin of transference from wheat to a less intensive type of agriculture. This is the margin to which this study is relevant. It is in this margin of transference that most of the shifting of resources between wheat and cattle production occurs as the variables affecting shifts change in their relative importance.

There are, of course, many localized areas within the two extreme areas of production that are susceptible to shifting. A complete delineation of all geographic areas that are susceptible to shifts is beyond the scope of this study. The discussion and analysis does apply in general, however, to most of the areas sensitive to shifts between wheat and livestock, and especially to areas where shifts may be determined on the basis of physical criteria alone.

### The Background: Historical Aspects

Historically, many shifting problems have occurred in the Northern Plains each year since the production of wheat and cattle began in the region during the late 1800's. Only two periods in history, however, have witnessed major shifts of sufficient proportions to create national policy problems with respect to the dire circumstances created by their aftermath. The first exodus from the Northern Plains occurred in the years intervening between the two world wars. This was the aftereffect of the expansion in wheat acreage which occurred during World War I. In response to phenomenal price increases accompanied by good weather conditions, farmers expanded their wheat acreage from 56 million in 1914 to 74 million in 1919 (harvested basis). Following a moderate cutback after the war, seeded acreage remained above the 60 million mark throughout the 1920's. <sup>3/</sup>

As foreign shipments fell off, domestic production continued to remain above pre-war levels as advances in mechanization made it possible to reduce the real cost of producing wheat and for the more successful operators to expand the size of the wheat producing unit. The great drought and depression of the 1930's combined forces to bring a second major disaster to the Plains. <sup>4/</sup> A high proportion of fixed costs incurred by firms in the area necessitated continued attempts to produce at maximum capacity levels, especially since production alternatives were practically nil in many

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<sup>3/</sup> Warren R. Bailey and Charles W. Nauheim, "Prospective Adjustments in Wheat Farming", U.S. Dept. of Agri., Bur. of Agri. Econ. (mimeo report prepared for distribution at 31st Annual Agricultural Outlook Conference, Washington, D.C., October 28, 1953), p. 1.

<sup>4/</sup> Loc. cit.

instances. This situation was extremely hard on small operators without reserves as well as those operators with high indebtedness brought on through over-optimism and high land investments during the temporarily favorable conditions existing during the war and the years immediately following.

Those who weathered the lean years of the 1930's received their due reward as history repeated itself in the 1940's. In response to an optimum combination of stimuli in the form of an unprecedented series of favorable weather years and price conditions, the sod-busting race was on again as managers and speculators again pushed back the margin of wheat production. Greater certainty with respect to price due to government non-recourse loans made profits relatively certain as long as the good weather would hold out. In addition, as impending government acreage restrictions approached reality, operators were quick to expand their acreage of wheat in order to establish as large a base as possible upon which future acreage allotments would be based, realizing that potential acreage allotments might possibly be capitalized into the value of the land should the acreage allotment program remain in effect for long. These factors tended to serve as impediments in holding back the margin of wheat production in sensitive areas until drought and surpluses brought trouble.

Bailey and Nauheim have aptly summed up the rest of the historical situation:

Early in War II, farmers were urged to plant feed and oil-seed crops and to hold down wheat acreage. Under a feed-price subsidy, the surplus wheat was fed to livestock. In the 4 years, 1942-45, an average of 300 million bushels were fed annually--200 million more than usual. The bins were cleaned. Beginning in 1945, large quantities of wheat were needed for export to both allied and occupied countries in Europe. Prices rose and farmers increased

plantings from 53 million acres in 1942 to an all-time peak of 84 million in 1949. Improved yields together with large plantings have resulted in crops of more than a billion bushels each year since 1944, except in 1951 when yields were exceptionally low.

By 1949 exports had tapered off and large wheat stocks again threatened. Acreage restrictions were invoked for 1950 but the Korean Incident abruptly changed the picture. Demand and price increased, restrictions were quickly removed and plantings again increased to about 78 million acres.

Greatly reduced export demand in 1952 has resulted in large wheat stocks--about 560 million bushels. An acreage allotment of 62 million has been announced for 1954 and marketing quotas have been voted. This represents a 21 percent reduction from the 1953 acreage . . . 5/

### Implications

Some of the underlying causes and criteria for determining shifts may be revealed by an analysis of past shifts, and may serve as a basis for a foundation for present research. It would be a mistake, however, in planning for the immediate future in analyzing potential shifts to formulate too many analogies or direct comparisons among conditions existing then and now. Certainly, the basic underlying causes would still remain the same, but changes in their relative effects prevent direct comparisons among conditions existing then and now. A rise in the general price level, technological and social changes, and changes in world outlook are among the factors that have served to alter the general situation existing today as compared to twenty or thirty years ago.

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5/ Bailey and Nauheim, op. cit., pp. 1, 4.

Technological advancements in both the wheat and cattle industries have served in effect to substantially enlarge the transition area between the two; i.e., they have made it possible to produce wheat and cattle in areas where their production prior to these advancements was virtually impossible. Development of new disease and drought resistant, stronger stemmed, higher producing varieties has had an important effect upon wheat production. The livestock industry has been affected by new and faster means of revegetation, water diversion and usage, and disease combating methods. Thus, the factors which determine the margin at which land use is shifted from livestock to crop production and vice versa have not only changed in value, but the rates at which such shifts can be made have also changed. For example, it has been assumed before that it is relatively impossible to reseed and re-establish range vegetation in any reasonable length of time once the land has been committed to wheat production. Technology has already begun to shorten this necessary transition period, as well as to increase the forage production potential once the shift has been accomplished.

So although historical incidents may be used as guideposts to the current situation, they must be tempered with relative changes in the relevant variables involved before they will be of value in analyzing current shift potentials.

Barring further outbreaks of hostilities within the next few years, further reductions in wheat acreage seem likely. Now, the question arises: how much of the pressure can be relieved by shifts to livestock production, and when and where should such shifts occur? Moreover, are there cattle producing ranches that should be in wheat, and to what degree would

countershifts, if they could be made, affect the shifts out of wheat? In light of the recent flood of both popular and experiment station literature urging managers to produce more grass and livestock, these are extremely important considerations. The crusaders were anxious to forestall future dustbowls and economic catastrophes when the impending decline in postwar international demand for wheat and grain exports simmered back down to normal levels.

Livestock production, in the overall picture, is not the panacea that popular opinion has created as the alternative to wheat in the Northern Plains. R. I. Throckmorton sheds some light on the estimated role of livestock and grass in the diverted acreage problem. He estimates that the use of the area diverted from wheat in 1950 ran something like this: grasses, 12 percent; legumes, 14; fallow, 30; other crops, 41. 6/

There are some very practical reasons why the percent diverted to grasses and livestock production is not greater, and will not likely become too much greater in the future. Some of the more obvious of these, of course, deal with government policies, lack of stock water, capital limitations, etc. Of great importance as limiting factors are the institutional problems, especially those related to land tenure; as well as social problems. All will be dealt with further in a later section which analyzes the factors affecting shifting in more detail.

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6/ R. I. Throckmorton, "Report of Conditions in the Great Plains as of April 1, 1950", cited by O. L. Mimms, "Diverted Acres in the West", Proceedings of the Western Farm Economics Association, June, 1950, p. 32.

Even with its limited importance in the overall picture, the margin between wheat and cattle is still extremely important in the marginal areas sensitive to shifts. Possibilities of shifting to other alternatives throughout the entire wheat area are currently being investigated in other studies.

## PART II.

## DEFINITION OF THE PROBLEM

Concerning shifting problems in general, Sherman E. Johnson has written:

Too little attention has been given to the problems involved in the shifting margins of both major and minor uses of land. Frequently the response to the changing outlook for farm products is too slow to keep up with a new source of demand. And then once the shift is started it may go too far. This leads to maladjustments in the use of land because after major changes have been made the process is not readily reversible.<sup>7/</sup>

The purpose of this study is to investigate a methodology for delineating firms sensitive to shifts between wheat and range forage production. With this relatively modest goal, it is hoped that the problem of estimating the effects of strategic shift variables in dryland areas of the Northern Great Plains might be made more tractable. Rules of thumb and general criteria can be treacherous if not tempered to take into effect the unique conditions confronting each firm. But they do serve as direction indicators in the planning process and, as such, their potential usefulness is very great.

A. The Theoretical Framework

Shift problems within the firm are problems of selecting enterprises and allocating resources among them in such a way as to yield an optimum

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<sup>7/</sup> Sherman E. Johnson, "Principles of Land Utilization", John F. Timmons and William G. Murray, editors, Land Problems and Policies, (Ames: Iowa State College Press, 1950), Ch. 5, p. 67.

in terms of net farm income over time. An enterprise has been defined as ". . . a line of production necessitating individual and distinct production treatment". 8/

### Enterprise Relationships

The individual firm within an area sensitive to shifts has three alternatives when considering its wheat-range forage production pattern; it may produce all wheat, all cattle, or some combination of both. The final organization of the firm is dependent upon the relationships between the two enterprises in light of the complete sum of environmental characteristics peculiar to the unit being considered.

When both wheat and cattle compete for essentially the same stock of resources, they are known as competitive enterprises. Under these conditions, and with a given supply of resources with which the firm must be run, an increase in the total physical product of wheat (cattle) due to an extension of additional resources to this enterprise, necessitates a decrease in the total physical product of cattle (wheat). For example, if the amount of wheat land is increased, a reduction in the cattle herd will be necessitated.

Two other types of relationships may exist between wheat and livestock enterprises. A complementary relationship exists when, on a given unit and with a given stock of resources, an increase in the total physical product of one enterprise is associated with an increase in the total physical

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8/ Lawrence A. Bradford and Glenn L. Johnson, Farm Management Analysis, (New York: John Wiley & Sons, Inc., 1953), p. 153.

product of the other. This is true even when resources are diverted to one by reducing input thereof in the other, as when livestock production is increased at the expense of actual crop acreage.

Situations of complementarity between wheat and livestock are quite rare in dryland shifting areas, if they exist at all. In many cases, it is possible for a wheat and livestock enterprise to exist side by side within the same firm, and yet present no outward indication of complementarity whatsoever. Topography, soils, and other conditions within the firm may divide the two enterprises, making them independent of each other with respect to most resources, especially land. This situation is especially evident on many ranches having a level expanse of land for wheat production, and a rough, broken area of native range. The enterprises may still compete, however, for certain resources; e.g., the purchase of a new registered bull may limit weed spraying activities and thus decrease wheat yields.

It is possible, of course, that "latent complementarities" may exist within certain units; investigations should be conducted to determine such possibilities. If such conditions are found to exist, the firm would profit by their subsequent development.

If, within a given firm, there are resources which have a zero opportunity cost <sup>9/</sup>, an enterprise may be added which will be of a supplementary nature. Supplementary enterprises do not compete for resources with other enterprises; neither do they complement others; they merely make use of

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<sup>9/</sup> I.e., they have no other alternative use and hence, no other means of yielding a potential net return.

resources that would otherwise remain dormant. If supplementary enterprises are added to wheat or livestock units, they are likely to be in the form of poultry, dairy, sheep or garden enterprises and not as a supplementary been project on a wheat farm or vice versa. This, of course, will vary over time as general conditions vary, and especially as the supply of available family labor with no opportunity cost varies.

The major type of enterprise relationship which is evident in sensitive shifting areas, then, is a competitive relationship between range forage-livestock production and wheat production.

#### The Theoretical Model

In general, net farm income will be increased, for a given time span, by shifting resources from wheat (cattle) to cattle (wheat) production, if, as a result of the resource shift the increment to net income from the additional wheat (cattle) exceeds the decrement in net farm income from reductions in the production of cattle (wheat).

The model relevant to the problem concerns the product-product relationship existing between wheat and cattle. The basic assumption of a product-product relationship is that prices can be varied while a significant portion of the resources used in common between the two enterprises can be held constant in type and in quantity. The basic theory for determining optimum enterprise combinations has been outlined by Heady. <sup>10/</sup>

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<sup>10/</sup> Earl O. Heady, Economics of Agricultural Production and Resource Use, (New York: Prentice-Hall, Inc., 1952), pp. 201-275.

With wheat and cattle competing for a given sum of resources within a given unit, the physical relationship between the two enterprises, or the manner in which they substitute for each other, must be determined as a first step in developing an estimate of the model.

There are three general directions in which wheat and cattle may substitute for each other: they may substitute at increasing, decreasing, or constant rates.

1. Increasing rates of substitution exist, if, as cattle is substituted for wheat, successively greater sacrifices in wheat output must be incurred in order to achieve a unit increase in cattle output, and vice versa.

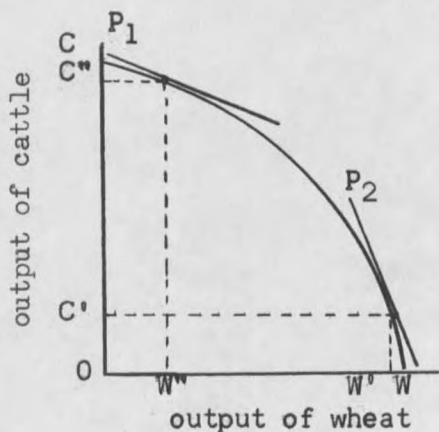


Fig. 1. Increasing rates of product substitution between wheat and cattle.

This results in the concave opportunity curve pictured in Figure 1. OW and OC represent total output in physical units if resources are shifted all to wheat or all to cattle, respectively. Curve CW represents a continuum of various combinations of wheat and cattle that can be produced with the same

(equal) resource outlay, hence, it is termed an "iso-product" or "equal-opportunity" contour. The slope of the line indicates the marginal rate of product substitution between wheat and cattle.

For example, assume that resources are being shifted from wheat to cattle, or that cattle output is being substituted for wheat output. If

increasing rates of substitution are valid in explaining the physical relationship between wheat and cattle, then the first unit by which wheat output is diminished would result in a rather large increase in cattle output. However, as successive constant decrements in wheat output occur, the corresponding increments to cattle output diminish, until a decrease of one unit of wheat output would result in virtually no change in cattle output. The marginal rate of product substitution of cattle for wheat is thus found to increase. The same situation is true in reverse in shifting from cattle to wheat.

2. Decreasing rates of product substitution exist between wheat and cattle if successively smaller sacrifices in wheat output would be required in order to achieve a unit increase in cattle output, and vice versa. This results in an opportunity curve convex to the origin, as shown in Figure 2.

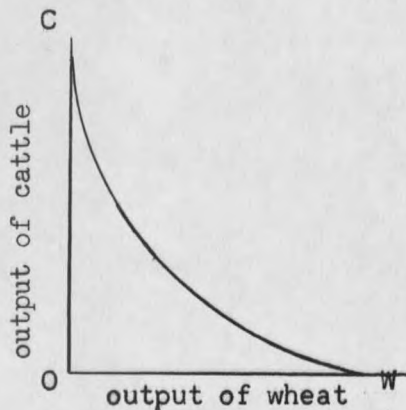


Fig. 2. Decreasing rates of product substitution between wheat and cattle.

If this situation is found, profits will increase continually until all of the resources are diverted to the production of one of the commodities. Decreasing rates of substitution are not likely to exist throughout the relevant range. <sup>11/</sup>

3. Constant rates of product substitution indicate constant sacrifices in the output of one enterprise as resources are

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<sup>11/</sup> See Heady, *op. cit.*, pp. 217-219.

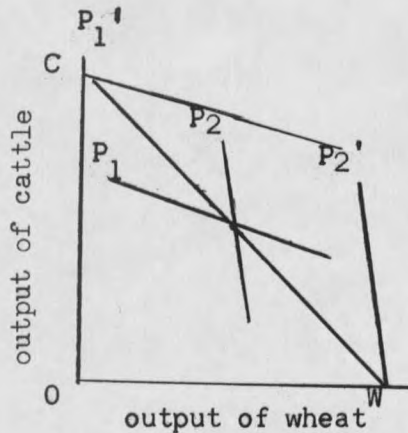


Fig. 3. Constant rates of product substitution between wheat and cattle.

diverted to production of the other. This results in linear opportunity curve CW in Figure 3. <sup>12/</sup>

The exact nature of the product-product relationship for wheat and cattle is open to considerable debate. The foundation for the opportunity curve

showing these relationships is based upon the nature of the production function, or

relationship between inputs (common to both) and total output, for each specific enterprise. The sparsity of data with which these production functions may be determined adds to the haziness of the problem. Production functions for wheat and for cattle will vary considerably from ranch to ranch as the determinants of the functions vary. Therefore, generalizations concerning the approximate nature of general relationships between wheat and cattle must be developed and interpreted with caution.

It does seem reasonable to expect, however, due to reasons to be developed later, that an area of constant substitution rates between wheat and cattle in areas highly sensitive to shifts might be expected over some limited range. For example, within this range, each hypothetical incremental yield of, e.g., 200 bushels of wheat, brought about by shifting

<sup>12/</sup> There is, of course, the possibility of a positively sloped function over certain segments of an opportunity curve, denoting complementarity.

resources from cattle to wheat, would reduce the cattle output by constant decrements.

In order for this situation to hold true, certain assumptions must be met. The production function for each specific enterprise must be either (1) linear, or (2) of such a nature that the increasing productivity from one enterprise just offsets the decreasing productivity from the other. <sup>13/</sup>

#### Price Considerations and the Economic Solution

An economic solution obviously cannot be reached merely on the basis of the physical relationships previously developed. In order to make use of physical relationships in arriving at an economic solution, a knowledge of the price relationship between wheat and cattle is necessary. This constitutes the second step in reaching an estimate of the relevant economic model.

If the prices of wheat and cattle are known, an "iso-revenue" line may be constructed showing all of the possible combinations of output that will yield the same amount of revenue. Lines  $P_1$  and  $P_2$  in Figures 1 and 3 represent "iso-revenue" lines for two different price ratios. An "optimum" solution is obtained by equating the marginal rate of product substitution with the inverse ratio of their prices. Geometrically, the slopes of the two lines will be equal (See Fig. 1). At this enterprise combination, income net of the costs of resources common to the two enterprises is made a maximum.

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<sup>13/</sup> See Heady, ibid., p. 208.

For example, in Fig. 1, a high relative price of cattle is represented by iso-revenue line  $P_1$ ; at its point of tangency with opportunity curve  $CW$ ,  $OW''$  of wheat and  $OC''$  of cattle will be produced. The opposite situation is represented by iso-revenue line  $P_2$ .

In Fig. 3, however, it can be seen that where linearity exists over wide ranges in the opportunity curve, the iso-revenue lines  $P_1$  and  $P_2$  will intersect opportunity curve  $CW$  rather than be tangent to it. This has a unique result in that rather than specifying an optimum combination of the two enterprises, it specifies an "all-or-none" solution. Resources are diverted entirely to cattle if the price ratio is less than the MRPS as demonstrated by  $P_1'$ , or all to wheat if the price ratio is greater than the MRPS, demonstrated by  $P_2'$ .

Since the solution thus far yields only a maximum of income over the cost of resources common to the two alternatives, some adjustment must be made for other resources used in the production process. A general solution of this problem in the sense of relating all relevant resources may be represented by the following equation:

$$\frac{\Delta_c}{\Delta_w} = \frac{P_w - MC_w}{P_c - MC_c}$$

where  $MC'$  represents the marginal direct expense <sup>14/</sup> for wheat and cattle. This solution maximizes the income net of costs of resources common to and unique to the two enterprises.

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<sup>14/</sup> Where "direct expense" refers to the cost of resources specific to each enterprise.

If compensation is not made for the marginal direct expenses, the assumption must be made that they are insignificant relative to the ultimate solution of the problem. If adjustment is made, it will change the slope of the price line, the degree of change necessarily determined by the relative proportions of the marginal direct expenses. There is no reason for expecting that a linear "iso-revenue" line would result in all cases from adjustments for direct marginal costs; it is possible that such adjustments may result in a curvilinear iso-revenue line. This situation would have a unique effect upon the character of the solution: rather than reaching an "all or none" solution, a curvilinear iso-revenue line would specify an optimum combination of output of both products at the point of tangency between the curvilinear iso-revenue line and the linear opportunity curve. For purposes of simplifying this analysis, however, it will be assumed that direct marginal costs are inconsequential and that the iso-revenue curves are linear.

#### Effect of Non-Homogeneous Resources

Since data are not available with which to compute actual marginal rates of product substitution between wheat and cattle, much of the rest of this discussion will be hypothetical in nature.

It has been stated before that when linearity does exist in the transformation function, it is likely to occur only within a limited production range. Heady <sup>15/</sup> has demonstrated that when resources of two different qualities are used, the opportunity curve will have a bend in it, if each

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<sup>15/</sup> Heady, op. cit., p. 216.

enterprise has a linear production function within the limits of the farm. Heterogeneity of resources, then, may cause "kinks" in the transformation function, indicating the possibility of various ranges of constant rates of substitution that vary as resource quality varies, thus changing the marginal rate of product substitution and the slope of the opportunity curve. Such kinks may also indicate conditions of complementarity or supplementarity in some instances. Figure 4 is a hypothetical illustration of such a situation:

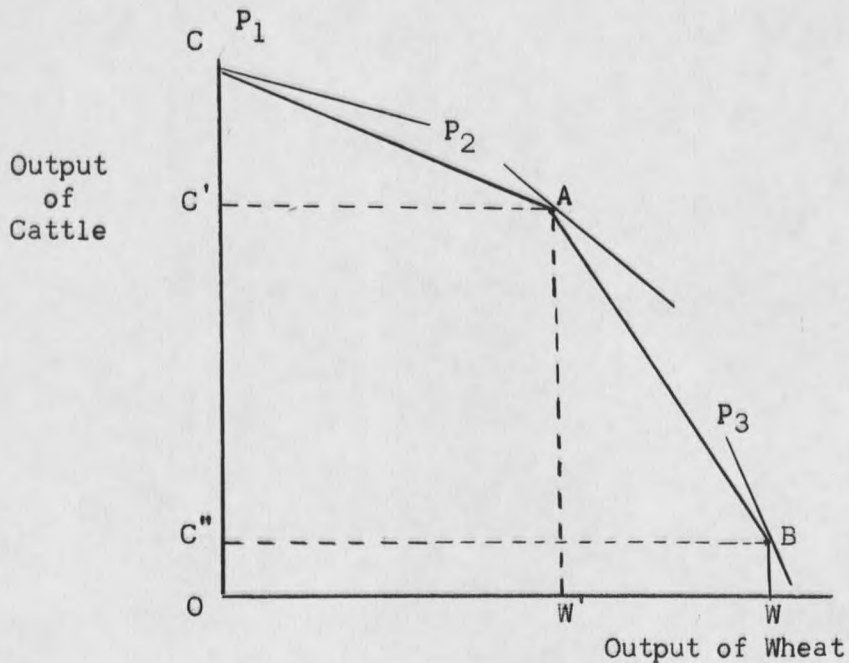


Fig. 4. Hypothetical transformation function between wheat and cattle.

This diagram has some significant features relative to the problem under discussion. The flat segments  $CA$  and  $AB$  represent two different ranges of constant rates of substitution as resource quality changes.  $BW$  represents

a possible range of complementarity; an operator producing wheat at maximum capacity  $OW$  could also produce  $OC''$  of cattle with the same resources. A similar range of complementarity existing for wheat is unlikely.

At point A on the opportunity curve of Fig. 4,  $OC'$  of cattle and  $OW'$  of wheat would be produced. This points the way to possible combinations of enterprises as ratios change, rather than a complete immediate shift over to the other extreme. For example, if prices change so that the slope of the iso-revenue line is less than segment AB of the opportunity curve but still greater than segment CA, the likely result will be to produce wheat and cattle in combination as suggested above. Then as the price ratio reaches a slope that is less than that of CA, a shift entirely to cattle would occur. This same process would occur in reverse if the shift is made from cattle to wheat and price ratios change in the opposite direction.

#### Time Considerations and the Non-Reversible Opportunity Curve

Thus far, the analysis has implied that the opportunity curves are reversible; i.e., that shifting can occur from wheat to cattle as easily as from cattle to wheat. In the "long run", given time for complete resource adjustment, this is possible. However, at any given point in time, the operator shifting from wheat to cattle is confronted with a different schedule of opportunities than the operator shifting in the opposite direction. The solution thus far achieved also assumes static price relationships over time, another unrealistic assumption.

Consequently, the preceding analysis has set forth the opportunities confronting a manager with a given sum of resources before they are committed

to the specialized production of either wheat or cattle or some combination of both. The opportunity curves of Figs. 1-4, then are long run opportunity curves. <sup>16/</sup> Once the resources are committed, the operator no longer is confronted with the same opportunities, and the short run opportunity curves become the relevant tools for decision making within the firm. This situation is graphically illustrated in Figure 5.

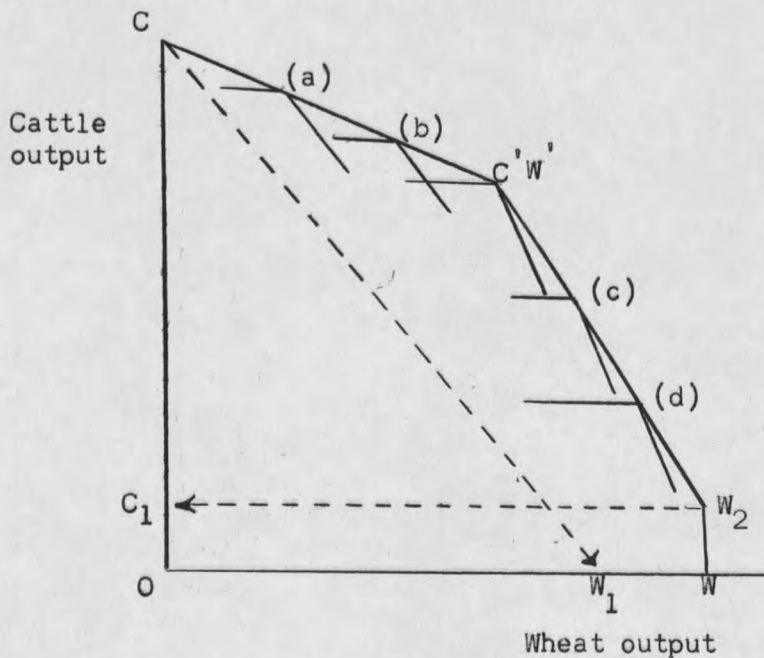


Fig. 5. Short and long run opportunity curves facing firms sensitive to shifts.

Assume that long run opportunity curve CW as shown in Figs. 4 and 5 is relevant in explaining the physical relationships existing between wheat and cattle within an individual hypothetical firm which initially is capable

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<sup>16/</sup> See Earl O. Heady, "Uncertainty in Market Relationships and Resource Allocation in the Short-Run", *Journal of Farm Economics*, Vol. XXXII, No. 2, May 1950, pp. 244-249.

of specializing in the production of either commodity. Before any resources are committed, the entrepreneur of this firm is faced with long run opportunity or planning curve  $CW$ ; he may select any combination of outputs represented on this continuum and produce them with the same supply of resources common to both enterprises.

If he has chosen to specialize in cattle production, however, the short run schedule of choices with which he is confronted is no longer represented by  $CW$ , but is depicted by short run opportunity curve  $CW_1$ . This indicates that in the short run it may be possible to increase wheat production from nothing to  $OW_1$  by diverting resources from cattle to wheat. This is possible because of the relative ease with which herds can be cut back while rangeland is plowed and seeded to wheat. It is possible that a complete shift from wheat to cattle would occur during one year. This would involve a considerable sacrifice in nonsalable specialized livestock buildings and equipment, especially on large units. Assume that the entrepreneur chose the combination of products represented by point (a) on the long run opportunity curve. <sup>17/</sup> Then, with a smaller cow herd, and some specialized grain producing equipment already available, it would be relatively easier to further increase wheat output. It would become increasingly easier to make a complete shift all at once as combinations (b),  $C^0W^0$ ,

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<sup>17/</sup> Actually, according to previous definitions, point (a) would represent an irrational enterprise combination from the standpoint of maximizing income. Because of linearity, the operator would ideally produce only at  $C$ ,  $C^0W^0$ , or  $W$  as the iso-revenue curve changes. It may be necessary to produce at a temporarily irrational product combination in order to reach an "optimum" position.

(c), and (d) are successively reached.

On the other hand, assume that the entrepreneur had diverted all resources to wheat production. Then his economic position would be maximized by producing  $OC_1$  of cattle, (since cattle are supplementary within this limited range), and  $OW$  of wheat. At  $W_2$ , however, the immediate short run potential for increasing cattle output beyond the supplementary range is practically nil. This, of course, is due to the time lag required for shifting from wheat to livestock which results from the 3-4 year minimum time span for reestablishing the ranges and building up the herd. Thus, it would take a minimum period of 3-4 years, depending on many conditions such as weather and prices, to move from  $W$  or  $W_2$  to  $C$  on the long run opportunity curve. The relative difficulty involved in shifting from wheat to cattle is represented by the horizontal segments of the short run opportunity curves.

It must be emphasized that the short run opportunity curves represent the same total resource outlay as the long run curve. 18/

The problem of unequal time spans for resource shifts in opposite directions is one of the most difficult problems encountered in making analyses of shifting situations. It is one of the major reasons why more shifts are not made from wheat to cattle.

#### Size Considerations

Size of unit is an extremely important consideration in evaluating

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18/ See Heady, Economics of Agricultural Production and Resource Use, op. cit., p. 247.

potential shifts. For example, it is common knowledge that more acreage is required for a livestock ranch than a wheat farm in order to achieve an equal income. Thus, it may be possible, or even desirable, under given circumstances, to shift small and uneconomic livestock producing units into wheat production or production of some other crop; whereas it would be impossible to shift a small wheat producing unit into cattle production at current or prospective prices. It is possible that such shifts may occur over time, despite the economic consequences, by developing livestock as a supplementary enterprise and extending it into the competitive range of relationships. Certainly some adjustments of size are necessary in many circumstances in order to establish an economically sound unit.

Very little is known about economies of size on wheat and cattle ranches in the Northern Great Plains, but a few ideas and hypotheses do exist. Kelso has stated that:

. . . within rather wide limits, costs and returns in cattle ranching are almost directly proportional to numbers of AU run. The limits are roughly between 150 AU as a minimum and 600 AU as a maximum. Within these limits the operator with incidental hired help can do all the labor. Beyond 600 AU it rapidly becomes a management proposition for the operator with practically all hired labor . . . about 90% of all ranches fall within the sizes . . . mentioned. 19/

If the carrying capacity of the range is known, then, an area of constant costs for the firm can be established.

The same thing is true, generally, with wheat farming, except that cost economies may exist over a greater range of size. Heady writes:

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19/ M. M. Kelso, How Much Can a Cattleman Pay Per AU For a Cattle Ranch?, unpublished mimeo, Montana State College, January 29, 1949.

Analysis of available engineering and cost data, however, makes it fairly evident that the greatest cost economies associated with units of different sizes are to be found in crop production where power units and machine combinations of high capacities can be substituted for labor and fixed costs can be spread over a large acreage . . . Large-scale cost advantages stand to be greatest in grain farming regions such as the wheat areas of the Great Plains . . . 20/

There is little, if any, empirical data with which to formulate a definite area of constant costs for wheat farming. Possibly such a range might exist between approximately 240 and 1000 acres, with units of under 240 acres still producing in varying areas of decreasing cost situations.

Heady and Shaw 21/ have reported that the sum of elasticities of resources used on Montana dry land crop farms is not significantly greater than 1.0. This would imply that there would be a substantial area of constant returns and subsequent linear production functions.

A comparison of size requirements may be shown by Fig. 6.  $C_1W_1$ , . . .  $C_nW_n$  represent opportunity curves for wheat and cattle production (similar to those shown in Figures 4 and 5) as resources common to both of them are increased by equal increments. Constant returns for wheat production are evident right from the start, as shown by the equal increments to output beginning with  $W_1$  on the X axis. However, the same supply of resources would still leave an entrepreneur in the increasing returns area for production of cattle. Successive increments to resources common to both would

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20/ Heady, ibid., p. 369.

21/ Earl O. Heady and Russell Shaw, "Resource Returns and Productivity Coefficients in Selected Farming Areas", Journal of Farm Economics, Vol. XXXVI, No. 2, May 1954, p. 246.

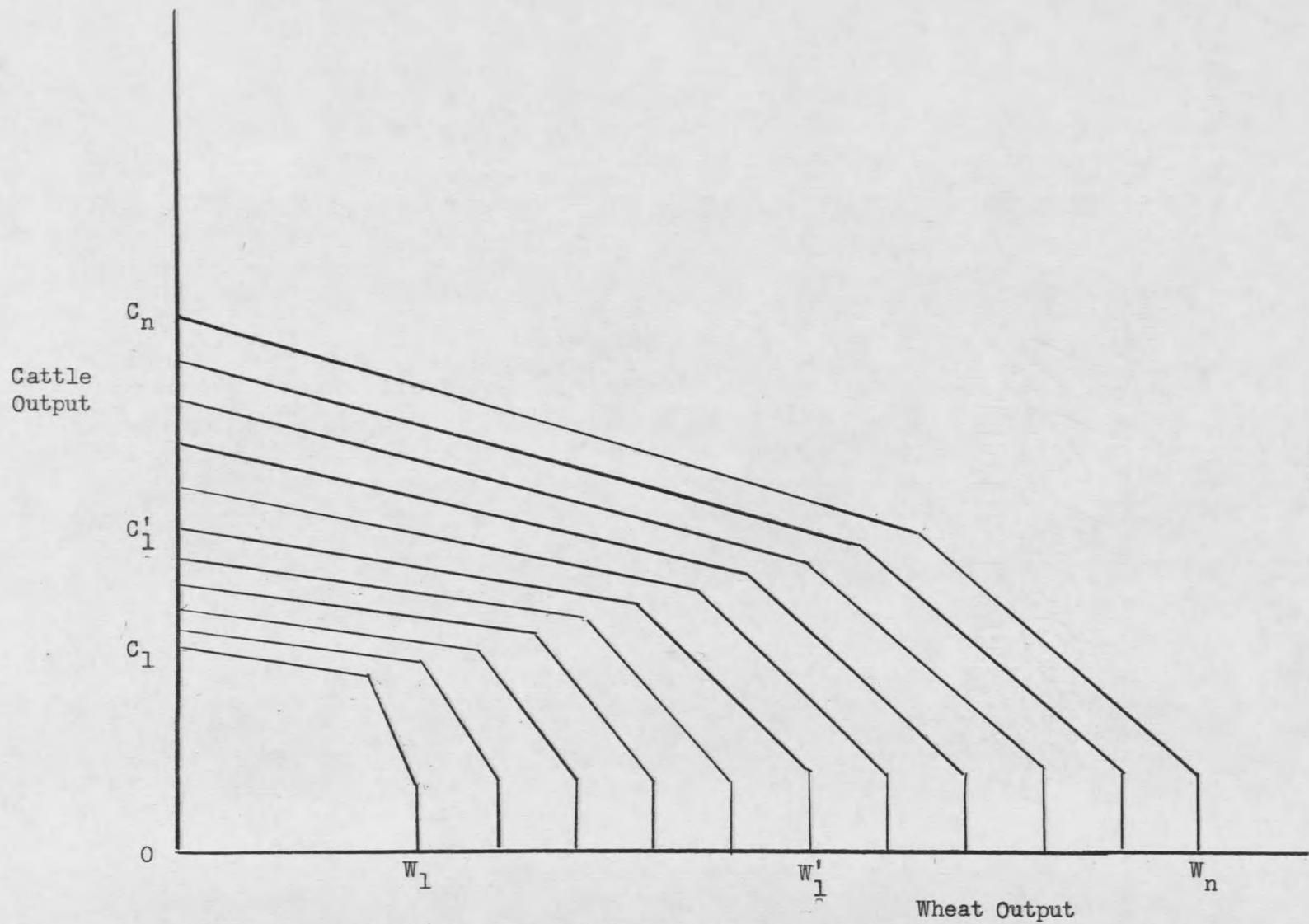


Fig. 6. Effect of added equal increments of resources (common to wheat and cattle production) upon output.

produce further constant increments to wheat output, but resources must be substantially increased until output level  $C_1$  is reached before the cattle rancher will be carried out of the production stage of increasing returns. The increments to cattle output will gradually increase, and then become constant when a size of unit considerably greater than the minimum size required to induce constant returns from wheat farming has been reached.

Thus, changes in relative prices would have different effects upon firms of different size.

#### B. Variables Affecting Shifting

In general, it may be said that there are three categories of environmental factors which, when considered together, comprise the whole of the environment facing the individual firm. These categories deal with the physical environment, the economic and social environment, and the technological environment. Since they determine the position and slope of the relevant production functions, these factors in turn determine the position and slope of the opportunity curves.

#### The Physical Environment

First of all, each firm is confronted with a physical or natural environment which establishes the outer boundaries of possible production alternatives as well as the physical production potential of what is actually produced. Thus, the complex interacting network of physical factors determine not only what can be produced, under given situations, but also how much or how little can be produced with the farmer's given supply of resources.

The physical factors which superficially seem to be the most important in determining shifts are those related to climate, soil and topography.

Climate at once poses a number of interesting problems and questions. The most significant of these are related to the variability of the weather around the critical level for plant growth and survival. The extremes of weather phenomena--droughts, blizzards, hailstorms, etc.--are the most disastrous. They are also the most difficult to predict. The effects of moisture variability are especially important. About the only thing that can be stated with any degree of confidence concerning the weather is that dry and wet years tend to follow each other in bunches. According to Clawson and Hochmuth,

It is a well-known fact that variations in precipitation do not occur randomly, but that dry years are frequently found associated together, and wet years likewise. During one of these periods of dry years there may be an occasional year when precipitation is above average. There will likely be considerable year to year variation in precipitation. It is not unlikely that a series of years with an annual precipitation averaging less than the long-time average precipitation will have occasional wet years. The occurrence of a few wet years in a dry series may mislead many people as to the seriousness of the numerous dry years. Similar considerations are pertinent when precipitation exceeds the long-term average. 22/

Some of the more important aspects of weather to be considered in relation to their effect upon shifts are precipitation, temperature, and length

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22/ Marion Clawson and Harold Hochmuth, Economic Use and Administration of a Fluctuating Forage Supply, U.S. Department of Agriculture, Bureau of Agricultural Economics, Berkeley, California, December 1941, p. 13. See also, Marion Clawson, "Sequences in Variation of Annual Precipitation in the Western United States", Journal of Land and Public Utility Economics, Vol. XXIII, No. 3, August 1947, pp. 272-287.

of growing season.

The presence or absence of moisture is a vital factor in spelling the subsequent success or failure of ranchers in the Northern Plains. It is well known that wet years, coupled with favorable prices, will cause the margin of transference from dry land range to wheat to be extended farther out into the critical areas. One report has estimated that during the 1948-52 period, 5.0 million acres or more of grass and other land previously somewhat stabilized was transferred to cropland and fallow to take advantage of the favorable conditions. This represented an increase in cropland of approximately 16 percent in the Mountain States. <sup>23/</sup> Due to the high fixed costs of mechanization for wheat production and the time lag required for a shift back to cattle, during which income will be limited or nil for several years, much of this land will continue under capacity operation until drought forces the operators to make a change in production. Then, policy problems will result as land is abandoned due to these and other reasons such as poor soil, etc.

It is not possible to select a critical level of rainfall which will apply to the area as a whole in serving as a measuring stick for shifts. The area is characterized by a semi-arid climate, with rainfall in most areas ranging from 10 to 20 inches. Yields at a given level of precipitation will necessarily vary from area to area due to changes in rates of evaporation, temperature, soil types, ground cover, prevailing winds, etc. As an

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<sup>23/</sup> H. H. Wooten, Major Uses of Land in the United States, U.S. Department of Agriculture, Washington, D.C., Technical Bulletin 1082, October 1953, p. 93.

illustration of the contrasting requirements of different areas, it has been found that wheat can be grown in central Washington on a lower annual rainfall than any place else in the United States. The arid limit in this section is about 9 inches per year, the rains coming in the winter and spring when the evaporation is at a minimum. In central Alberta, about 11 inches of spring and summer rain is required. In western Texas, where the summer temperature is 20 degrees higher and with much the same seasonal distribution of rainfall, about 19 inches of precipitation marks the arid limit. <sup>24/</sup> Any shifting decision based on rainfall will necessarily have to be evaluated in terms of the complete array of local conditions.

Not only is the total annual precipitation important, but also the seasonal precipitation is of extreme significance. A high level of annual rainfall that comes at the wrong time for promoting plant growth is of little benefit. One study has indicated that the May-June rain may be the most important to wheat yield. <sup>25/</sup> It also indicated that an increase of 1 inch of rainfall in this period would seem to increase yield by 3 bushels. In July, 2 inches of rainfall was found to be required to maintain growth and yield set by the May-June rainfall. More than this critical amount of rainfall will again boost yields. Reasons listed for the importance of this pre-season rainfall were that it penetrates deeply, evaporates slowly, and

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<sup>24/</sup> Harold D. Hughes and Edwin R. Henson, Crop Production, (New York: The Macmillan Company, Reprint, 1948), p. 441.

<sup>25/</sup> George W. Robertson, The Climate of Alberta's Soil Climate Zone II as a Factor in Crop Production, unpublished M.S. thesis, University of Alberta, 1948.

conditions the subsoil for the succeeding year, particularly where rainfall is low during the growing season. 26/

It has been found in other studies that yields, up to a certain point, appear to be proportional to the quantity of water above the minimum requirements for crop production. Thus, a precipitation of 14 inches would produce, not one-sixth more, but double the yield produced by a 12-inch precipitation, as there would be twice as much water above the minimum requirement. 27/ This would indicate a possible linear relationship over a limited range. The depth of the moisture in the ground at seeding time has been found to be a rather effective indicator of a rough estimate of the yield that may be expected.

Another character of rainfall affecting crop growth is its intensity. One study points out that under certain conditions, especially on clay soils, showers of less than 0.15 inch are of no value in increasing soil water. 28/ Just as very light rains are of literally no value because of rapid evaporation, very heavy rains are of limited value for the soil is often unable to absorb much of the moisture.

Hurtt, in analyzing Weather Bureau records from the Miles City station over a 62-year period (1878-1939) reports that the annual average precipi-

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26/ Loc. cit.

27/ O. R. Mathews and John S. Cole, "Special Dry Farming Problems", Soils and Men, U. S. Department of Agriculture Yearbook, 1938, p. 684.

28/ F. Shreve, "Rainfall as a Determinant of Soil Moisture", Plant World, Vol. XVII, No. 1, 1914, pp. 19-26.

tation of 13 inches falls into two distinct groups. 29/ He has classed the normal distribution of rainfall throughout the growing season as follows:

	<u>Inches</u>	<u>Percent</u>
April.....	1.05	11
May	2.04	22
June	2.57	28
July	1.51	17
August	1.06	12
September	<u>.95</u>	<u>10</u>
Total....	9.18	100

Source: Loc. cit.

In further analysis of the 62-year record, Hurtt indicates that:

. . .if total rainfall is less than 70 percent of the 9.18-inch spring-summer average, or 6.4 inches, the effects on range are usually so serious as to cause a condition of drought.

. . . Frequency of drought is one of the most significant features of the 62-year record. . . Thirteen years brought drought conditions. Nine years fell below 6.4 inches of growing-season rainfall. A tenth, 1917, came close to 6.4 but had rather well-distributed rainfall. Four years, 1881, 1890, 1900, and 1937, received more than 6.4 inches of rainfall but had four or more very dry months during the growing season and were considered drought years. The Miles City average of one drought in 5 years is a typical example of northern Great Plains weather, and is substantiated by a 60-year record, ending in 1939, at Havre, Mont., not far from the Canadian border and about 250 miles northwest of Miles City. 30/

The critical level of rainfall is thus somewhat lower for range forage production than for wheat. The type of vegetative cover found in various

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29/ Leon C. Hurtt, Managing Northern Great Plains Cattle Ranches to Minimize Effects of Drought, U.S. Department of Agriculture Circular No. 865, Washington D.C., March 1951, p. 2.

30/ Hurtt, ibid., pp. 2-3.

areas serves as an indicator of amount of rainfall.

Just as there is an optimum amount of precipitation for each type of vegetation, there is also an optimum mean temperature. Temperatures below or above these critical values retard growth through retardation of chemical action or excessive transpiration, respectively. Associated with temperature in determining the effectiveness of available precipitation is wind velocity. Optimum temperatures are especially important to fall and spring seeding, and to calving and lambing operations.

The length of the growing season measured by the average number of consecutive frost-free days is likewise significant in determining the predicted success with which wheat can be grown in marginal areas. The Northern Plains has a fairly short, but variable, growing season, necessitating the adaptation of plants with a relatively short period required for seed maturation. Extremely late spring frosts and early fall frosts are not uncommon and may cause much damage to the feed value of fall range, or to seed maturation, and to early plant development in the spring. The average length of the growing season for Montana over the years ranges from 80 days in Powell County to 156 days for Custer County. 31/ In general, normal plant growth requires a minimum frost-free season of 90 days. 32/

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31/ Montana Department of Agriculture Labor and Industry, Montana Agricultural Statistics, cooperating with the U.S. Department of Agriculture, Bureau of Agricultural Economics, Helena, Montana, Vol. II, 1948, p. 11.

32/ William E. Maughan, "Supplementary Climatic Notes For Montana", Climate and Man, U.S. Department of Agriculture Yearbook 1941, p. 966.

Climate has been emphasized because of its extreme importance in determining the production pattern of the Plains. Various studies have been made in an attempt to discover some key to the weather cycle in the region, in order that disastrous results of future droughts and adverse weather phenomenon might be reduced to a minimum. <sup>33/</sup> Common, but erroneous, also, is the belief, fostered by 10 years or so of good rainfall, that at last the weather in the Plains is changing permanently. The uncertainty and weather risks that are brought by the weather are major factors in causing resource mis-allocation in the region.

Soils -- Climate, together with the nature of the parent material and the type of vegetation are the major determinants of the type of soil that exists in a region. The condition of the soils of the Plains has been summarized as follows:

The soils of the Great Plains have a superficial appearance of uniformity, particularly on the more level lands. They vary widely in their productivity, however, even within small areas. While they are generally fertile, they exhibit wide diversity in their texture, their depth, and their water-holding capacity. Almost any of them will produce fairly good crops in wet years, but in dry years only those that absorb and hold large quantities of water and resist wind erosion can be farmed successfully. <sup>34/</sup>

Ion exchange and subsequent leaching has been limited due to light rainfall, and few of the natural elements have been lost. Many areas have a

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<sup>33/</sup> M. A. Bell, Probable History of Seasonal Cropping Conditions in the Havre Area As Shown By Tree Ring Growth, 1784 to 1949, Chart Neg. No. T60B, Northern Montana Ag. Exp. Sta., Havre, Mont.

And R. A. Dightman and M. E. Beatty, "Recent Montana Glacier and Climate Trends"; Proceedings of the Montana Academy of Sciences, Vol. XII, 1952, pp. 127-139.

<sup>34/</sup> Bennett, et. al., "The Problem: Subhumid Areas", Soils and Men, U.S. Department of Agriculture Yearbook 1938, p. 69.

very shallow, rocky soil which is unsuitable for crop production since soil nutrients for producing an adequate crop are usually lacking. Some measure of soil productivity is essential in analyzing a potential shift, as well as a good knowledge of the structure and water-holding capacity of the soil. Soils with a poor moisture-holding ability are poor risks in areas close to or chronically below the danger zone for adequate rainfall.

The type and condition of the soil is also a vital factor when considering potential range reseeding operations. Impervious soils incapable of absorbing available moisture may dry to depths below those from which the plant derives its water and nutrients, and thus render range forage production impossible. A well developed soil will make a more efficient use of available moisture, and will thus increase the ease with which reseeding operations can be conducted, as well as decrease the time lag necessary for establishing a good stand of grass. Some soil types are so erosive, sterile and rough as to render reseeding impossible. <sup>35/</sup> The diversity of types of soils in the region makes it all the more important to make a complete analysis of the soil groups of the individual ranch before ultimate shifting decisions are reached.

Topography--Topography refers to the slope and contour of the land; i.e., the "lay" of the land. Topography and "rockiness" of land determine (1) the possible degree of mechanization that can be achieved for crop production, and (2) the requirements and availability of stock water.

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<sup>35/</sup> Laurence A. Stoddart and Arthur D. Smith, Range Management, (New York: McGraw-Hill, Inc., 1943), pp. 58, 59.

In many instances, shifts from wheat to cattle could probably be made except for the limiting factor of stock water. In a study made in 1949, 60 wheat farmers were interviewed concerning their plans if a 25 percent cut in wheat acreage were to go into effect. Out of 60, 27 reported that they could not shift to livestock due either to lack of pasture or of water. Lack of water alone accounted for 19 impossible shifts. 36/

The stock water problem is intimately related to the problems of both moisture and topography. Moisture in the form of available stock water supply is a necessary factor in setting up a livestock operation. It is well known on the Plains that he who controls the water also controls the range. The amount of water and number of watering holes necessary depend upon the conditions of each particular grazing unit. In very rough country, cattle should not be forced to go more than 1/2 mile for water, but can travel from 2 - 2 1/2 miles in flat country. This would require a water hole for every 1-20 sections depending upon the topography. Cattle will require on the average about 10 gallons of water per day. 37/

In summary of physical and natural conditions affecting shifts, it may be said that the diversity and infinite variation of weather conditions pose as very powerful variables in determining the pattern of production to be carried on in the Plains. It may be that they overshadow many of the economic and social factors in their importance relative to the problem of analyzing potential shifts.

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36/ O. L. Mimms, "Diverted Acres in the West", Proceedings of the Western Farm Economics Association, 1950, p. 33.

37/ Stoddart and Smith, op. cit., p. 319.

The Economic and Social Environment

Secondly, the firm is confronted with an economic and social environment.

As a result of specialization and commercialization, the farmer is directly concerned with costs of production and prices of output, since his goal is either that of increasing the level or reducing the variation in net farm income, or some compromise between the two.

Fluctuations and difficulties in predicting accurately the pattern of prices extending into the future makes this area of analysis particularly difficult. Trends into the future calculated on the basis of previous data are risky. But use of outlook and price data available as evidence for decision making is certainly better than a blind stab in the dark. Time series of past prices are particularly helpful in analyzing price variation and consequent variations in net farm income.

Size has already been briefly discussed in connection with the economic model for the study. It is necessary to note some social implications of size, however. Society has been a major conditioner of the size of unit, especially in the Great Plains. Through policies designed to establish family farms on land alienated from the public domain, many less than optimum-sized units have been established in the area. This has been the basis for many of the policy problems confronted by administrators. Associated with total size of unit is the problem of scattered holdings, which in and of themselves may prevent shifts due to difficulties encountered in managing such units.

Related to the economic and social environment is the significant problem of tenure. Oftentimes tenure conditions may be the major reason for preventing otherwise desirable shifts. Landlords with no other means of income are reluctant to undergo a three or four-year transition period in shifting back to grass and livestock. Certainly the ratio of leased land to total acreage operated has an important bearing on who makes the shifting decisions and why they are made.

The personal quirks and psychological make-up of the farmer has a great deal to do with shifting. Personal preferences based on past experiences may create a possible divergence between a private and social optimum, and in a sense, are a social cost as well as an added opportunity cost to the producer. Some managers, by their very nature, are more readily convinced of the desirability of undertaking a risky shift, whereas their neighbor down the road would never even consider such a move.

Capital limitations and financial considerations may prevent shifts, despite favorable outlook for undertaking them.

Isolation and sparsity of population has always been a major factor in determining land use. Lack of schools in remote areas is a significant factor in limiting the adoption of a year-around range and livestock operation on a dry land wheat farm. Wilson <sup>38/</sup> has indicated that about 25 percent of Montana dry land wheat farmers in one area studied live in town either part or all of the year.

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<sup>38/</sup> Unpublished data from a survey of 400 farm families in 19 school districts, from a study in progress by E. A. Wilson of the Montana Agricultural Experiment Station, cited by Mimms, op. cit., p. 33.

### The Technological Environment

The technological environment, although influenced to a large degree by capital availability, is so important that it warrants separate, even though brief, consideration.

Not only does technology decrease the time span necessary for shifting from wheat to livestock, but it also has some important aspects in relation to the efficiency of production of separate commodities. Oftentimes, rather than shifting, it may be more profitable from the long run point of view to adopt new practices or techniques in producing either range and/or livestock or wheat. Oftentimes, this possibility is overlooked or minimized.

One of the most important features of technological considerations is the contribution they make to timeliness of operation, making it possible to get the right thing done at the right time more often.

#### C. Summary

A complete analysis of all of the variables relevant to the problem situation could probably never be achieved. Although much of the preceding is descriptive in nature, the point to be emphasized here is that in areas of such complete uncertainty as the marginal areas of the Great Plains, a systematic recognition of the strategic factors is necessary in order to minimize the risks of operation. All of the enterprises and all of the factors must be considered together, with their collective effect upon the farm firm over time. This is a difficult task, but it must be accomplished in as nearly complete fashion as possible.

D. The Hypothesis

The outstanding implication from this brief survey of the economic characteristics of firms in the area and the environment within which they operate is that, for many, decisions as between the production of wheat and range forage are determined, over a significant range, by non-price factors. As a consequence of this, the hypothesis to be tested might be set forth as follows: Firms sensitive to shifts between wheat and range forage production may be separated from those which are not on the basis of non-price variables.

## PART III.

## EMPIRICAL INVESTIGATIONS: TESTING THE HYPOTHESIS

Careful adherence to the nature and essence of the hypothesis to be tested is a prerequisite to establishing empirical models for testing it. The hypothesis to be tested in this study <sup>39/</sup> concerns whether or not firms sensitive to shifts between wheat and range forage production can be delineated from those that are not on the basis of non-price variables.

In a major sense, the elements of the hypothesis necessitate the establishment of a dichotomous classification; the testing of this hypothesis would require a technique for classifying ranches or areas into either one of two types of agricultural production. The problem of land classification according to best use is an old problem and needs no review here. It is usually difficult to make an exhaustive type of classification with such a procedure. The overlap between groups is likely to be substantial, and subjective judgments may reduce the value of such a classification.

In comparison with other techniques, the statistical method of discriminant analysis appears to be a promising device for approaching the problem. The similarity between it and the standard multiple regression technique is substantial, and consequently some of their characteristics will be compared at various stages in the analysis. The major difference between the two, however, may be noted at the outset. Multiple regression, if used in this study, would require that the dependent variable (type of

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<sup>39/</sup> See p. 49.

agricultural production) be quantitatively expressed; whereas discriminant analysis would merely provide an index as the basis for a two-way classification. Thus, it may be possible to obtain results from discriminant analysis that are more significant than could be obtained from multiple regression due to the efficiency of obtaining an "either-or" answer rather than quantitatively expressed results.

#### A. The Linear Discriminant Function

Although the discriminant function has had fairly wide application in the natural science field, its use has been limited in economic and sociological investigations. The investigator is unaware of any application of this technique in the field of agricultural production economics research. Although the technique itself is not new, the fact that it has never been used yet in farm management analysis justifies its use from a purely experimental point of view, especially when its attributes are considered in connection with the problem at hand. Thus, the potential usefulness of the discriminant function in testing the hypotheses of the study is another hypothesis in and of itself.

#### Review of Work Previously Done

The discriminant function itself is related to that area of statistical analysis dealing with the use of multiple measurements in discriminating among groups.

The first work on discriminant analysis appeared in 1936. It was the preliminary result of an effort by R. A. Fisher to develop a more refined classification tool for the purpose of classifying plant specimens into

two groups on the basis of several measurable variables common to each group. 40/

It is natural that such a tool would be developed in the biological fields, where there are many difficult taxonomic problems, but also where rather refined measurement techniques have been devised. Where classifications are extremely precarious due to a substantial amount of overlap among groups on the measurements made on each group, there is need for a refined classification tool which can reduce this overlap. Ordinarily, problems of this type are treated statistically by testing the null hypothesis to see if there is a significant difference between sample means. Such a method leaves much to be desired in that it does not take into consideration the effect of more than one character or measurement on each group at a time, nor does it consider the interrelation of a wider range of relevant variables. 41/

Cox and Martin 42/, in a rather widely used example, used a discriminant function in classifying soil samples into two groups; those containing

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40/ R. A. Fisher, "The Use of Multiple Measurements in Taxonomic Problems", Annals of Eugenics, Vol. VII, Pt. II, (1936), pp. 179-188. Fisher's work on discriminant functions was culminated in two further papers published in the Annals of Eugenics; "Statistical Utilization of Multiple Measurements", Vol. VIII (1938), pp. 376-386; and "The Precision of Discriminant Functions", Vol. X (1940), pp. 422-429.

41/ Palmer O. Johnson, Statistical Methods in Research, (New York, Prentice-Hall, Inc., Second printing, 1950), pp. 343-344.

42/ G. M. Cox and W. P. Martin, "Use of a Discriminant Function for Differentiating Soils With Different Azotobacter Populations", Iowa State College Journal of Science, Vol. XI (1937), pp. 323-331.

the organism *Azotobacter*, and those without. Three sets of measurements were taken on each of two groups; one of which contained the organism *Azotobacter*, and one of which did not. Measurements taken on each of the 286 samples studied were:

$X_1$  = pH

$X_2$  = amount of readily available phosphate

$X_3$  = total nitrogen content

Then, by computing a discriminant function, and testing it for statistical significance, these three characteristics in linear combination were found to discriminate quite accurately between the two types of soil studied.

Outside the natural science fields, the use of discriminant analysis has been extremely limited. Two studies made in the field of economics warrant brief mention. In the first application, the method was used by Durand <sup>43/</sup> in analyzing a set of financial data to arrive at a classification of good and bad loans. In the second instance, it was used to distinguish between the prices of producers' goods and the prices of consumers' goods on the basis of certain measurements connected with their behavior during the business cycle. <sup>44/</sup>

This sketchy sampling of the work done with discriminant analysis will serve to illustrate the possible applications of the tool as a classification

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<sup>43/</sup> D. Durand, "Risk Elements in Consumer Installment Financing", Financial Research Program, Studies in Consumer Installment Financing 8, National Bureau of Economic Research (New York, 1941), p. 125.

<sup>44/</sup> G. Tintner, "Some Applications of Multivariate Analysis to Economic Data", Journal of the American Statistical Association, Vol. 41 (1946), p. 476.

method having potential merit in the field of agricultural economics. 45/

### The Empirical Model

Assume two samples of  $n_1$  and  $n_2$  observations upon which  $p$  variables  $X_1 \dots X_p$  can be measured in each sample and that the observations are classified into two groups:  $n_1$  in (currently) dryland crop areas and  $n_2$  in (currently) range livestock areas. With these data, two means for each variable can be computed, since  $X_1 \dots X_p$  variables are common to both samples:

$$(1) \quad \begin{array}{l} \bar{X}_{1w} = \frac{1}{n_1} \sum_{i=1}^{n_1} X_{1i} \\ \vdots \\ \bar{X}_{pw} = \frac{1}{n_1} \sum_{i=1}^{n_1} X_{pi} \end{array} \quad \text{and} \quad \begin{array}{l} \bar{X}_{1c} = \frac{1}{n_2} \sum_{j=1}^{n_2} X_{1j} \\ \vdots \\ \bar{X}_{pc} = \frac{1}{n_2} \sum_{j=1}^{n_2} X_{pj} \end{array}$$

where the subscripts  $w$  and  $c$  identify the variables related to wheat and cattle units, respectively.

A series of differences between means is then computed:

$$(2) \quad \begin{array}{l} d_1 = \bar{X}_{1w} - \bar{X}_{1c} \\ \vdots \\ d_p = \bar{X}_{pw} - \bar{X}_{pc} \end{array}$$

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45/ For another very recent study in the natural science field, see R. S. Bigelow and C. Reimer, "An Application of the Linear Discriminant Function to Insect Taxonomy", The Canadian Entomologist, Vol. LXXXVI, No. 2, Feb. 1954, pp. 69-73.

(continued on following page).

The basic problem now is to set up a function of the type:

$$Z = \sum_{k=1}^p a_k X_k, \text{ or,}$$

$$Z = a_1 X_1 + a_2 X_2 + \dots + a_k X_k + \dots + a_p X_p$$

where:

$k$  = variables (1, ..., p)

$Z$  = a type of index number for discriminating between groups after a critical value of  $Z$  has been determined.

$X_k$  =  $p$  variables  $X_1, \dots, X_p$

$a$  = the computed coefficient of the  $k^{\text{th}}$  variable, showing its relative weight or importance in determining the value of  $Z$ .

The principal virtue of this tool which makes it especially adaptable to this study is that it will establish a linear function or combination of the variables that will distinguish between the two groups better than any other possible linear function of the same variables, provided that it is statistically significant.

By maximizing the ratio of squared differences between the means of  $Z$  for the two groups to the within group variation of  $Z$ 's, the foundation is established for computing the  $a_k$  coefficients. The maximization of this ratio leads to a set of simultaneous equations, as demonstrated

(concluded from previous page).

For those interested in doing actual work with discriminant analysis, two bibliographies are invaluable: George W. Brown, "Discriminant Functions", Annals of Mathematical Statistics, Vol. XVIII, No. 4, Dec. 1947, pp. 514-527; the other appears in Palmer A. Johnson, op. cit., pp. 356-357.

originally by Fisher, solvable for  $a_k$ . These equations are of the general form:

$$\begin{aligned} S_{11}a_1 + S_{12}a_2 + \dots + S_{1p}a_p &= d_1 \\ S_{12}a_1 + S_{22}a_2 + \dots + S_{2p}a_p &= d_2 \\ \vdots & \\ S_{1p}a_1 + S_{2p}a_2 + \dots + S_{pp}a_p &= d_p, \end{aligned}$$

where the  $S$ 's denote the pooled sums of squares and products within groups. The  $a_k$ 's as computed are proportional to the estimates of the coefficients which yield a  $Z$  to serve as a basis for discriminating combinations of variable values into one of two groups.

A test of statistical significance must now be employed in order to have a basis for accepting or rejecting the linear discriminant function as computed. The statistical hypothesis that must be tested concerns the question as to whether or not there is a significant difference between the two groups of samples for the function  $Z$ ; if there is, then apparently the shifting margin can be ascertained by the computed discriminant function.

With the use of a variable

$$D^2 = \frac{n_1 n_2 (a_1 d_1 + \dots + a_p d_p)}{n}$$

a variance ratio can be established:

$$F = \frac{(n-p-1)D^2}{p(1-D^2)}$$

where  $F$  is a "test" variable with the "F" distribution with

$$\begin{array}{l} n_1 = p \\ n_2 = n-p-1 \end{array} \left. \vphantom{\begin{array}{l} n_1 \\ n_2 \end{array}} \right) \text{ degrees of freedom}$$

Then, if the calculated value of "F" is less than the table value of F, the function may have arisen purely by chance. If the calculated "F" is greater than the table F, then within an assigned probability of error, there is a distinguishable difference between the two groups.

If the null hypothesis has been rejected, a critical area can be determined for discriminating between wheat and cattle ranches on the basis of comparison between the computed critical value and the computed Z for a randomly drawn ranch. Having selected an individual ranch with the same measurements  $X_1, \dots, X_p$  with which the function was calculated, the hypothesis must be tested that the individual belongs to the first population.

Calculate:

$$\bar{a}_w = a_1 X_{1w} + \dots + a_p X_{pw}$$

$$\bar{a}_c = a_1 X_{1c} + \dots + a_p X_{pc}$$

where  $a_1$  represents the previously computed coefficients, and  $X_1$  represents the measurements made in arriving at the discriminant function.

To determine the critical point of discrimination, compute:

$$\frac{\bar{A}_w + \bar{A}_c}{2}$$

Then set up the test variable B, by computing:

$$B = a_1 X_1 + a_2 X_2 + \dots + a_p X_p$$

where a has the same meaning as previously and  $X_1, \dots, X_p$  represents the measurements made on the ranch for which the hypothesis is being tested.

Then if B is equal to or greater than the above computed critical point of discrimination, the hypothesis that the individual ranch should belong to

the cattle ranch population is rejected, and it is subsequently classified as a wheat farm.

Thus the value of  $Z$ , calculated with known values of the respective variables and calculated estimates of coefficients, would draw a fine line to distinguish "dry crop" areas from "range livestock" areas. 46/

#### B. Application to the Case at Hand

##### Necessary Data

The first step in applying the research technique to the research problem as previously defined is to define two populations; one predominately wheat and one predominately livestock. It must then be determined which of the variables discussed in Section II are the most amenable to common measurement on each population and to subsequent use in establishing the discriminant function. Once decided, a random sample must be drawn from each universe and pertinent data recorded.

In a sense, each variable chosen represents, at least indirectly, a hypothesis concerning the relevance and relative importance of the variable

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46/ The preceding constitutes a simplified presentation of the method. The technical reader or research worker should refer to the following references for a more extensive presentation of the theory and computational methods involved:

1. P. O. Johnson, *op. cit.*
2. G. Tintner, Econometrics, (New York: John Wiley & Sons, Inc., 1952), pp. 96-102.
3. Paul G. Hoel, Introduction to Mathematical Statistics, (New York: John Wiley & Sons, Inc., Sixth printing, 1951), pp. 121-126.
4. Cyril H. Goulden, Methods of Statistical Analysis, (New York: John Wiley & Sons, 2nd ed., 1952), Ch. 17, pp. 378-393.
5. A. McFarlane Mood, Introduction to the Theory of Statistics, (New York: McGraw-Hill, 1950), pp. 299-301.

in discriminating between the two groups. Thus, the hypothesis is established that the following three variables are powerful enough to discriminate between wheat and cattle ranches:

- $X_1$  = total acres operated  
 $X_2$  = ratio of leased/owned land  
 $X_3$  = total annual precipitation in inches

#### Sources of Data

Schedules originally used in a study by Gray and Baker <sup>47/</sup> were the source of series in variables  $X_1$  (total acres) and  $X_2$  (ratio of leased/owned land) for stock ranches.

The universe for this study was designated as follows:

A cattle ranch is defined as a range livestock organization which produces at least 50 percent of its gross income from beef cattle. A family-operated cattle ranch is one in which the labor and management is furnished primarily by the operator and his family.....A commercial family-operated cattle ranch is defined primarily with respect to size. In general, it is a cattle ranch, which, on the basis of 1944 prices and operating conditions, produced a gross value of products ranging from \$1,200 to \$20,000. Also, certain....other criteria served to eliminate ranches that have less than 5 acres of range per head of livestock....Also ranches having unusual values of livestock sold were eliminated....Also excluded were the cattle ranches of operators or owners who worked more than 100 days off the ranch during the year or had excessively high or low investments per ranch. <sup>48/</sup>

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<sup>47/</sup> James R. Gray and C. B. Baker, Organization, Costs, and Returns on Cattle Ranches in the Northern Plains, 1930-1952, Montana State College Agricultural Experiment Station Bulletin 495 in cooperation with the Bureau of Agricultural Economics, U.S. Department of Agriculture, Bozeman, Montana, Dec. 1953.

<sup>48/</sup> Ibid., p. 6, for a description of sampling procedures, refer to pp. 8, 9.

Series in the same variables for wheat farms were obtained from a set of schedules originally used by Fienup 49/ in a study of resource productivity.

The universe for the study is defined as:

. . . non-irrigated farms in Montana Type of Farming Areas III and IV (northeast Montana: spring wheat) and VI and VII (north central Montana: mixed spring and winter wheat). . . . The 156 farmers sampled constituted 0.555 percent of the universe. . . .50/

Series in  $X_3$  (total annual precipitation in inches) were obtained from the U.S. Weather Bureau's 1951 summary for Montana. 51/

The  $X_3$  measurement for each of the 274 ranches was based on data from the weather station closest to each ranch. Where ranches occurred between two weather stations, a rough interpolation was used to arrive at the measurement.

#### The Analysis:

The merits of a classification tool such as discriminant analysis which takes into account the interrelationships of several variables is apparent when considering the task of making a finite classification on the

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49/ Darrell F. Fienup, "Resource Productivity on Montana Dryland Crop Farms, Montana Agricultural Experiment Station Mimeograph Circular 66, Bozeman, Montana, June 1952.

50/ C. B. Baker, "Resource Productivity in Dryland Farming", Proceedings of the Western Farm Economics Association, Vol. XXV, 1952, p. 36. For a discussion of the sampling procedure, see Fienup, op. cit., pp. 38-41.

51/ United States Department of Commerce, Weather Bureau, Climatological Data, Montana Annual Summary, 1951, Vol. LIV, No. 13.

basis of singly considered variables where the overlap is so great as to render accurate classification impossible.

For example, if the ranches were to be classified on the basis of total annual precipitation in inches alone, the overlap would be tremendous. Frequency distributions compiled for each universe show that each is greatly skewed to the right. For illustrative purposes, the graphic distributions would approximate those of Figure 7.

It is obvious that very few sample members could be classified accurately due to the substantial amount of overlap as shown by the shaded area. It would be impossible to set an arbitrary level of total annual precipitation as the dividing point between wheat and cattle production and reach a meaningful classification due to this overlap and to the other factors which influence the minimum amount of precipitation needed on a particular ranch. The same difficulty would arise in trying to make a finite classification on the basis of any other single variable.

The further development of the analysis will show not only how this overlap can be reduced, but also how other variables can be added in the linear combination which will best discriminate between wheat and cattle ranches.

The discriminant function calculated on the basis of the three previously mentioned variables was found to be:

$$(1) \quad Z = X_1 - 63.92209 X_2 - 1881.479 X_3$$

After testing the significance of this equation, it was concluded that there is less than one chance in a thousand that a function such as this

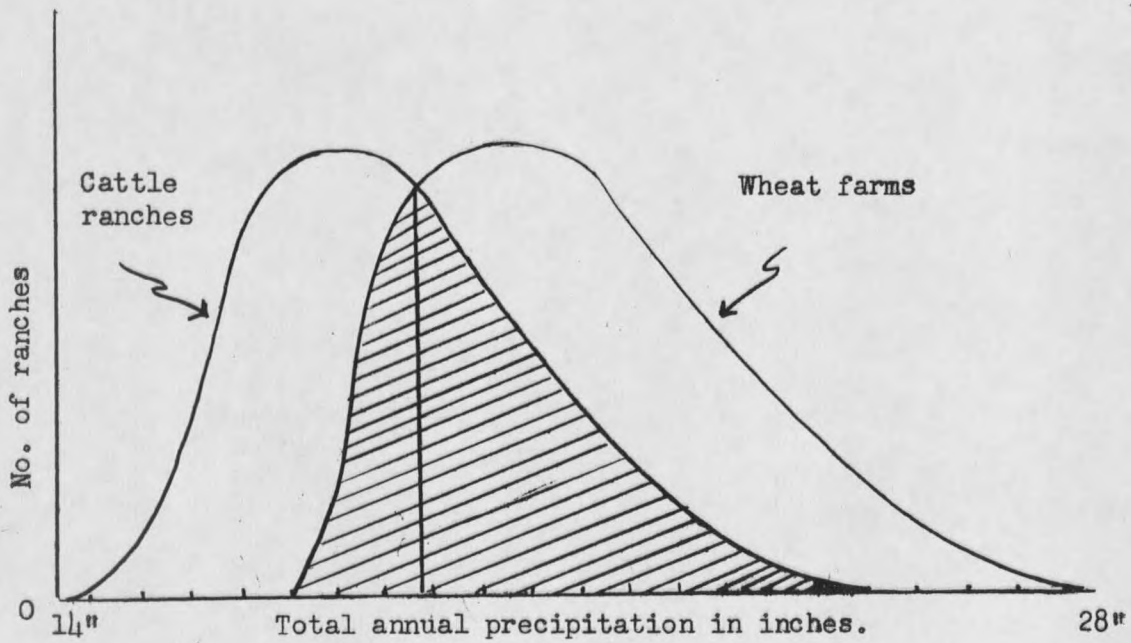


Fig. 7. Frequency distributions showing number of wheat and cattle ranches at each level of total annual precipitation. (Hypothetical data)

could have arisen purely by chance. <sup>52/</sup> Equation (1) thus apparently would achieve a maximum discrimination between the two groups on the basis of measurements used.

The critical level for shifting is then determined.

Since:

$$\bar{a}_w = -34,643.83359 \text{ and}$$

$$\bar{a}_c = -23,537.064641,$$

then the critical level, represented by the mean of these two values, is -29,090.4493.

If a calculated Z for a particular ranch or farm results in a larger negative number than this, the unit would be classified as a wheat farm; if the calculated Z results in a smaller negative number, then it would be classified as a cattle ranch.

According to equation (1) the factors that would contribute to high negative values of Z and subsequent classification as wheat farms are high values of total precipitation and ratio of leased/owned land, and low values of size measured in total number of acres operated.

In arriving at a smaller negative number, and classification as a cattle ranch, then the reverse of the above is true. Lower values of total precipitation and ratio of leased/owned land and correspondingly higher values of total number of acres operated are necessary if the individual unit is to be classed as a cattle ranch.

To see what effect the discriminant function has upon reducing the overlap and establishing a sensitive shifting area, a Z was calculated for

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<sup>52/</sup> The basic data required to calculate this discriminant function and an appropriate test of significance are included in Appendix Tables III and IV.

each of the 274 members of the samples. The results of this series of calculations are summarized in Figure 8.

This figure shows the effects of the variables used in determining the shifting margins. The upper bar represents the division of the 123 cattle ranches into three categories, on the basis of their calculated Z values. Moving from left to right, or from cattle to wheat, it is observed that precipitation and the ratio of leased/owned land both increase, while total acreage managed per unit decreases. The reverse is true in transference from wheat to cattle in moving from right to left along the lower bar. Category I in both cases represents, according to data used, the areas having the greatest relative advantage in the production of each commodity; Category II represents individual units still having an advantage in the production of one commodity over the other; Category III represents ranches that may be susceptible to shifts from one type of production to the other. Thus, roughly a fifth of the cattle ranches and a fourth of the wheat farms were, in 1951, on the basis of data used, susceptible to shifts. Equation (1) thus classifies 76.64 percent of the 274 sample members in the group to which they belong.

Total annual precipitation is, by itself, a powerful factor according to the results of this analysis. For example, in cattle ranch category I, with the averages of all other variables remaining constant at the levels indicated, a rise in the average precipitation from 13.12 inches to 20 inches would result in the classification of these ranches as wheat farms; in cattle ranch category II, it would only require a rise from 15.35 inches to about 17.5 inches to achieve the same result.

Classification of cattle ranches (percent in each category)			Classification of wheat farms (percent in each category)		
I	II	III	III	II	I
48.78%	25.20%	26.02%	21.2%	29.8%	49.01%
1) Ave. Z value: -16,384.8	-26,193.7	-33,878.6	1) -25,993.2	-32,103.0	-40,046.5
2) Ave. total annual precip.: 13.1	15.4	17.1	2) 15.0	17.1	20.4
3) Ave. ratio L/O 28.6	29.4	35.2	3) 28.4	31.5	50.6
4) Ave. No. acres 9,797.8	4,770.0	3,671.7	4) 3,975.3	2,068.0	1,566.3
			← SHIFTING MARGIN →		
$\bar{a}_c$	$\bar{A}$	$\bar{a}_w$			

Fig. 3. Classification of 274 sample ranches on the basis of their calculated Z values.

It may be noted further that the average tenure and precipitation conditions for category II of both wheat and cattle ranches closely parallel the average conditions found in the sensitive shifting areas, although the size factor varies considerably.

### C. Limitations of the Method

As mentioned before, this is an experimental venture with a statistical method new to farm management analysis. The results obtained apply only to the specific populations studied and to the specific 1951 data and cannot be transferred to the present or future without data modifications.

But the results are suggestive, at least, of what might possibly happen were a similar classification to be made under similar circumstances.

The most obvious limitations stem from the fact that many of the variables explaining shifts are subjective and hence unmeasurable; some variables that are measurable have not been included due to limitations of time and resources. It is possible that a function that would discriminate much better than the one calculated in this study could be achieved by the addition of more variables and further data refinements.

Another question arises as to whether or not the discriminant function actually yields results that are any better than can be obtained with standard multiple regression and correlation techniques.

Brandow and Potter <sup>53/</sup> made a comparison between the two techniques in their analysis of social participation data. Their comparison showed that

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<sup>53/</sup> Op. cit., pp. 325, 326.

the independent variables had the same direction of effect upon the subsequent outcome of social participation, which was the item being predicted or estimated in both cases. The relative importance of each variable was also similar in results from both the discriminant analysis and the multiple regression techniques. The  $R^2$  obtained indicated that slightly over half of the observed variation in social participation was associated with covariations in the independent variables used. 54/

A similar comparison was carried out in this study in order to gain a crude idea of the relative effects of each technique in determining sensitive shifting areas.

A linear function of the form

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$

was fitted for the same 274 sample ranches, where:

Y = percent of total acres operated in grain harvested,  
and

$X_1, X_2, X_3$  have the same meaning as in discriminant analysis,  
viz., size, tenure, and precipitation, respectively.

The calculated estimating equation is stated as follows:

$$(2) \quad Y = -4.7228 - 0.001356 X_1 + 0.04619 X_2 + 1.6680 X_3$$

$$(0.0001794) \quad (0.03277) \quad (0.3633)$$

$$\frac{-2}{R_{1.234}} = 0.270687$$

The estimates of the standard errors of the regression coefficients are represented by the figures in parenthesis immediately below the b coefficients. On the basis of these standard errors, there is much less

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54/ Loc. cit.

than one chance in a thousand that coefficients  $b_1$  and  $b_3$  could have arisen purely by chance, and thus they are highly significant. The probability of  $b_2$  arising purely by chance is much greater, approximately 16 times out of a hundred, and thus at the 95 percent level of confidence it is not significant. This is interesting, inasmuch as tenure has a greater effect in the discriminant analysis classification than does size.

Roughly 27 percent of the observed variation in the dependent variable, (percent of land in grain harvested), may be attributed to co-variation in the three independent variables. With this  $\bar{R}^2$ , there are less than five chances in 100 that the true value is less than .41 with  $N = 100$ . With  $N = 274$  in this study, the value of  $\bar{R}^2$  as thus computed is highly significant. At this point, one of the major pitfalls encountered in making comparisons between multiple regression and discriminant analysis must be noted and emphasized. It is extremely difficult to formulate a dependent variable for multiple regression which will convey approximately the same meaning as the dichotomous classification in discriminant analysis. Considerable discretion must be exercised in formulating the dependent variable if a direct comparison is to be made; oftentimes such formulations will be impossible. For example, the dependent variable used in this analysis includes only harvested grain; it excludes fallow land, and land used for other crops. A reformulation of the dependent variable taking into account these vital considerations would be necessary if an attempt were to be made in increasing the significance of the squared correlation coefficient.

Despite these difficulties, and the inadequacy of the dependent variable as formulated, the previous clues as to the significance of the

regression coefficients are meaningful.

Likewise, the following comparison between the coefficients of the two computed equations is interesting:

(1') Discriminant function:

$$Z' = X_1 - 63.92209X_2 - 1881.479X_3;$$

(2') Multiple regression:

$$Y' = X_1 - 34.0491X_2 - 1,229.6522X_3. \quad \underline{55/}$$

Thus, this comparison agrees essentially with that of Brandow's and Potter's: the coefficients in both the above equations are of approximately the same relative importance in determining the final outcome of shifts, and have the same direction of effect upon determining land to be in wheat. The inadequacy of the dependent variable used in the preceding multiple regression analysis precludes drawing any further implications from the comparison.

The test of hypothesis thus indicates that the possibility does definitely exist for determining empirically a margin of transference between wheat and cattle in dry land areas. Moreover, the preceding analysis implies that large numbers of farms are insensitive to price variables. Yet a significant area exists wherein shifts may be determined on the basis of price variables. The importance of moisture has been forcefully demonstrated. Thus, it seems possible that moisture and perhaps other biological and climatological conditions may dictate land use regardless of price

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55/ These coefficients are derived from formula (2) by converting  $b_2 = \text{unity}$ , thus making equations (1') and (2') more easily comparable.

considerations in some critical areas, which is a factor well known to those familiar with the Northern Plains.

D. The Budget Method and Shifting Analysis

The estimated impact of a shift on an individual firm can be made by use of the budget method in which programs, alternative to a current plan of operation, are synthesized and ultimately compared relative to the effect of each on net income. Before any shift is actually undertaken, it should first be undertaken on paper. Uncertainty precludes accurate estimates in many instances, but some compensation may be made for future drouth years making the budget more realistic. Any well conceived plan is apt to be better than no plan at all.

As mentioned in Section I, certain historical aspects may serve as guideposts to a current situation. In this connection, one possibility of obtaining an idea about the future is to go back and see what did or would have happened in the past. It is possible to use historical time series in price, weather and other variables in a "reverse-budgeting" technique.

Jones <sup>56/</sup> compares the alternatives of shifting part or all wheat land to crested wheat grass on a typical southwest North Dakota wheat-cattle ranch during a high price level period. Under these conditions, he points out, on the basis of constructed budgets, ". . . that operators of wheat-cattle ranches in this or comparable areas in the Northern Plains can shift

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<sup>56/</sup> Lloyd E. Jones, "Stabilizing Farming by Shifting Wheat Land to Grass in the Northern Great Plains", Journal of Farm Economics, Vol. XXXII, No. 3, August 1950, pp. 375-390.

wheatland to grass with very little change in income." 57/

In taking into consideration the extremes in weather phenomenon, he states that

" . . . in addition to budgets demonstrating farm performance under average conditions, information as to the effect of variations in weather on annual production, organization, and income is apparently needed in appraising alternative systems." 58/

He then constructs a series of budgets demonstrating these effects over a 14-year period (1929-1942). Concluding, he states that it seems possible to reduce production and income variation over a long period of time by shifting from wheat to crested wheat grass for livestock. 59/

Sitler 60/ makes use of secondary data in comparing returns from "average-sized" wheat and livestock producing units in Colorado during the period from 1924 through 1952. His preliminary conclusions agree substantially with those of Jones. His analysis shows that wheat was generally less profitable than livestock during the years 1929-1944, although the trend then reversed, with wheat yielding a higher income for a series of years than cattle. 61/

57/ Ibid., p. 378.

58/ Loc. cit.

59/ Ibid., p. 389.

60/ Harry G. Sitler, Returns From Wheat and Grass, preliminary unpublished manuscript, Colorado A & M College, Fort Collins, Colorado, 1954.

61/ Ibid.

Thomas and Mumford 62/ investigated the effects of permanent and temporary retirement of wheat land, with crested wheat grass being substituted. Their results showed a steadily increasing total farm income as steep, low-producing land was retired from wheat production. 63/

A rotation, or temporary retirement of wheat land appeared to have no economic advantage on the more productive wheat lands. However, it was pointed out that such shifts may be necessary from the standpoint of erosion control and/or soil fertility considerations. 64/

The budget method is an indispensable tool for analyzing the impact of a shift upon the farm since it forces a systematic consideration of many of the most significant factors affecting changes in farm and ranch organization as shifts are made. It may be complementary to the discriminant function. Once a ranch has been classified by this method, the budget may be used to check the logic of the classification and to investigate possible production alternatives within a sensitive area.

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62/ Thomas and Mumford, op. cit.

63/ Ibid., p. 3.

64/ Ibid., p. 4.

## PART IV.

## SUMMARY AND CONCLUSIONS

Recent developments in the agricultural situation have intensified numerous problems confronting the agricultural producers of the Northern Great Plains. Among the most important of these is the problem of determining the advisability of potential shifts between wheat and range forage production in dryland areas.

This study represents an attempt to isolate areas sensitive to wheat-range forage shifts. The hypothesis arising from this problem proposed that such areas could be delineated from those that are less susceptible to shifts on the basis of non-price variables alone--i.e., natural and climatological factors which affect patterns of land use.

Subsequent statistical investigations confirmed this hypothesis, subject to the probabilities and methodology limitations previously developed.

The analysis of the problem leads to some important inferences. It seems apparent that there are large areas where organization (as between range forage production and wheat production) tends to rigidity; but a significant area (approximately 24 percent of the ranches included in the two populations) shows distinct tendencies toward sensitivity to shifts. Approximately 12 percent of these were predominately stock ranches; and the remaining 12 percent were wheat.

Methodologically, the study has developed a possible approach to an analysis of the shifting problem. Moreover, it has shown that the discriminant function, although new to the field of farm management analysis, may

be worthy of further investigation in developing its potential usefulness as a classification tool.

Classification as an end in itself may be a useless and expensive pastime. Therefore, it is to be hoped that such classificatory tools as discriminant analysis may be applied as means to the ends of achieving more meaningful analyses of significant problems requiring investigation.

From a practical standpoint, this study points out the necessity of considering each firm in its individual internal and external environment in reaching ultimate shifting decisions. It is possible that further refinements of the methodology presented here would be amenable to entrepreneurial use.

Future research progress in this area will definitely hinge on the extent to which agricultural economics can serve as an "integrating" or "coordinating" science. Certainly the task ahead can be most effectively accomplished through the close cooperation of physical and social scientists.

73.

· A P P E N D I X

Appendix Table I. Data for wheat farms used in calculating discriminant function and multiple regression coefficients.

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
1	41.07	1120	28.57	16.56
2	46.41	960	33.33	16.56
3	50.14	1097	29.17	16.56
4	49.09	1760	18.18	16.56
5	43.00	400	100.00	20.05
6	45.94	320	100.00	13.94
7	50.00	1280	50.00	16.57
8	52.50	1200	100.00	16.57
9	43.75	1280	0	16.57
10	50.00	480	0	16.57
11	48.44	960	66.67	12.93
12	50.00	2400	100.00	14.41
13	58.54	410	60.98	12.93
14	50.34	1760	100.00	20.31
15	45.14	1440	0	20.31
16	46.82	2200	45.45	20.31
17	48.61	1440	0	20.31
18	75.00	400	0	20.31
19	70.83	1200	6.67	20.31
20	69.38	800	100.00	18.56
21	50.11	918	100.00	18.56
22	49.68	1560	100.00	18.56
23	50.00	800	20.00	18.56
24	41.25	400	0	19.12
25	33.02	2120	84.91	27.17
26	57.69	1040	7.69	19.05
27	33.84	1055	12.69	27.17
28	12.39	920	43.47	16.56
29	47.62	3360	77.38	16.56
30	50.00	1400	50.00	16.56
31	59.21	3040	73.68	15.83
32	44.37	586	100.00	21.76
33	37.88	1320	0	17.55
34	38.33	1800	0	17.55
35	43.70	460	65.22	17.55
36	51.79	1120	14.29	15.35
37	64.10	1560	61.54	15.35
38	51.92	520	100.00	15.33

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table I. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
39	46.88	320	0	14.99
40	38.18	1480	21.62	16.56
41	32.38	800	60.00	16.56
42	2.00	1450	0	21.76
43	25.00	440	0	20.63
44	28.59	780	100.0	17.57
45	25.00	640	50.00	13.94
46	12.22	3520	45.45	13.94
47	29.47	526	0	13.94
48	3.73	6300	66.27	13.94
49	4.40	5000	100.00	18.61
50	3.33	7500	0	18.42
51	20.83	4800	50.00	16.57
52	16.67	3000	0	16.57
53	30.81	2720	11.76	16.57
54	42.86	2800	100.00	16.57
55	49.69	1284	24.92	14.41
56	2.20	2731	35.12	14.99
57	38.75	800	40.00	14.41
58	34.78	2760	39.13	12.93
59	41.41	1280	25.00	14.41
60	32.43	2960	16.22	14.41
61	45.83	960	0	14.41
62	52.19	640	0	14.41
63	79.17	720	44.44	20.31
64	64.38	1600	20.00	20.31
65	11.61	1680	78.57	20.31
66	11.79	1840	89.13	20.31
67	19.15	4700	68.09	20.31
68	41.95	1280	100.00	20.31
69	34.81	1307	26.55	18.56
70	27.46	2130	48.83	18.56
71	9.73	2620	65.65	18.56
72	30.11	880	0	18.56
73	35.42	2640	56.82	18.56
74	48.05	2560	18.75	18.56
75	46.30	1620	39.51	18.56
76	21.76	3520	50.00	18.56
77	51.82	880	0	19.12

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table I. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
78	41.96	1120	42.86	19.12
79	37.50	320	12.50	20.77
80	33.75	320	100.00	19.12
81	47.09	860	0	19.12
82	48.00	1000	16.00	19.12
83	47.77	471	0	20.77
84	32.32	1120	21.43	19.12
85	44.46	560	0	19.12
86	42.97	640	100.00	19.12
87	39.58	960	100.00	19.12
88	8.35	2600	13.85	19.80
89	23.65	2600	75.38	19.80
90	8.99	5180	92.66	19.80
91	11.08	4740	22.36	19.80
92	10.63	1600	40.00	19.80
93	13.23	3680	7.61	19.80
94	37.50	480	100.00	19.80
95	4.00	14000	21.43	19.80
96	7.38	15650	8.95	19.80
97	10.87	5520	23.19	19.80
98	12.12	6600	21.21	19.80
99	15.64	6720	33.33	16.67
100	16.04	3360	33.33	16.67
101	19.53	6400	100.00	16.67
102	5.53	15000	74.40	18.47
103	19.69	960	100.00	16.67
104	33.00	2000	0	18.47
105	18.23	1920	50.00	18.47
106	9.96	4520	7.08	18.47
107	10.66	2720	100.00	16.67
108	12.58	1320	12.12	16.67
109	13.33	480	33.33	16.67
110	26.10	2720	0	18.47
111	33.75	800	0	18.32
112	40.74	1080	40.74	27.17
113	30.08	2560	62.50	27.17
114	16.67	1200	13.33	27.17
115	37.12	617	0	18.32
116	34.18	1960	100.00	27.17

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table I. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
117	32.66	2740	0	27.17
118	52.97	1480	0	27.17
119	43.75	1600	60.00	27.17
120	38.40	1000	0	16.56
121	45.83	1920	0	16.56
122	6.81	3820	93.71	21.76
123	44.44	1800	0	20.63
124	23.84	2538	39.40	15.35
125	5.24	12500	52.00	13.94
126	18.26	1440	55.56	13.94
127	10.56	1250	0	21.76
128	45.70	1046	100.00	17.55
129	30.64	2180	58.72	21.76
130	33.29	826	0	21.76
131	25.37	2069	7.73	21.76
132	44.12	680	0	20.63
133	50.00	480	66.67	15.35
134	42.50	2000	86.00	20.63
135	18.60	860	67.44	15.35
136	17.92	240	0	15.35
137	16.16	2760	11.59	15.35
138	5.06	17700	62.15	15.35
139	37.89	1800	64.44	20.05
140	42.79	1720	41.86	20.05
141	23.75	7200	0	17.57
142	38.68	2120	0	20.05
143	32.05	880	22.73	17.57
144	58.33	264	0	17.57
145	52.92	1200	50.00	17.57
146	28.43	1020	35.29	17.57
147	6.80	3750	17.33	13.94
148	13.24	1360	0	13.94
149	23.44	640	0	13.94
150	12.48	2580	87.50	13.94
151	28.75	2000	68.00	13.94

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table II. Data for cattle ranches used in calculating discriminant function and multiple regression coefficients.

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
1	0	40,000	65.00	17.29
2	1.15	6,500	0	8.11
3	0	10,027	42.41	18.11
4	4.25	2,000	0	18.27
5	4.00	10,000	0	23.52
6	.20	15,000	60.00	15.83
7	1.19	8,000	16.00	19.44
8	3.33	15,000	66.67	16.94
9	0.33	15,000	66.67	16.65
10	2.20	5,000	38.40	19.44
11	2.14	7,000	9.14	23.94
12	0.50	10,000	47.60	12.17
13	2.53	9,500	10.53	18.27
14	0	6,240	7.69	25.54
15	0	15,000	2.67	19.44
16	1.25	8,000	16.00	19.44
17	2.31	6,500	18.76	15.46
18	0	30,000	53.33	13.72
19	0.27	18,000	44.44	13.72
20	4.62	6,500	18.46	23.52
21	0	12,560	20.38	16.11
22	0.49	3,500	0	16.54
23	1.48	5,400	50.00	16.94
24	4.02	1,740	18.39	15.83
25	0	5,000	6.40	15.83
26	0	58,400	1.64	15.71
27	0	5,000	68.40	11.91
28	0	8,000	8.50	15.22
29	0	10,000	60.00	18.11
30	0	5,800	0	11.36
31	1.67	6,000	10.67	16.11
32	0	11,520	41.67	13.36
33	0	13,160	19.45	15.29
34	0	5,000	100.00	13.72
35	2.19	5,540	36.46	12.46
36	0	13,840	36.99	15.29
37	0	21,000	27.43	15.29

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table II. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
38	0	5,760	84.72	15.29
39	0.24	4,200	4.88	15.29
40	1.26	8,900	21.35	15.29
41	0	7,360	21.74	15.29
42	0	7,000	9.14	15.29
43	0	9,000	22.22	15.29
44	0	3,400	18.82	15.29
45	0	4,000	16.00	15.29
46	1.25	6,400	100.00	15.29
47	.40	5,000	40.00	9.16
48	0	6,400	70.00	12.70
49	0	9,200	44.34	12.70
50	0	1,160	17.24	16.27
51	0	450	28.89	13.02
52	0	4,000	50.00	12.82
53	0	3,840	41.67	14.97
54	15.12	2,116	7.23	12.82
55	0	3,920	0	12.82
56	0	1,560	0	9.34
57	1.58	1,900	27.37	14.97
58	.21	1,920	0	14.97
59	1.50	16,000	28.13	14.97
60	.10	8,000	32.50	14.97
61	9.77	1,280	0	13.88
62	0	2,705	2.96	13.99
63	3.33	1,200	100.00	16.52
64	0	558	100.00	19.12
65	1.04	1,920	33.33	16.86
66	0	4,300	32.55	16.94
67	4.46	2,240	37.50	15.22
68	6.72	2,440	22.95	16.65
69	0	2,700	44.84	19.23
70	0	2,760	69.57	20.00
71	0	2,560	50.00	12.17
72	7.24	760	15.79	18.92
73	.14	11,000	36.36	19.12
74	0	5,740	66.55	19.44
75	0	1,280	75.00	16.86
76	0	1,280	100.00	12.96

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table II. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
77	6.04	1408	0	15.79
78	1.73	2600	3.08	11.45
79	0	1527	26.20	12.96
80	1.00	3000	33.33	10.69
81	0	3840	33.33	14.48
82	0	2780	11.51	10.69
83	1.73	4400	31.82	10.69
84	2.70	1445	44.29	10.69
85	1.76	4160	15.38	8.11
86	1.05	1910	16.75	12.96
87	0	1740	9.20	16.11
88	0	20000	5.40	15.29
89	.12	6080	44.74	13.72
90	1.00	12000	16.67	13.88
91	0	4500	15.56	15.29
92	7.39	2570	17.12	12.46
93	7.33	3410	0	18.27
94	0	7100	100.00	12.82
95	2.55	11000	54.55	12.46
96	0	8000	25.00	12.82
97	2.10	4760	35.29	12.46
98	0	4100	14.63	12.82
99	.20	5000	44.00	14.97
100	0	3040	0	12.82
101	1.19	5900	15.25	12.82
102	0	5760	55.56	12.82
103	0	5000	25.60	9.34
104	0	2180	88.07	16.86
105	6.00	5000	45.60	16.94
106	2.40	6800	23.53	16.94
107	14.00	2500	12.80	20.23
108	0	2700	0	23.94
109	0	3320	80.72	20.00
110	.41	8500	48.24	15.83
111	0	3500	0	18.59
112	1.33	3770	0	12.96
113	2.74	2920	49.32	11.45
114	0	880	9.09	11.45
115	.21	19360	20.66	13.36

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table II. (continued)

Farm No.*	Percent of land in harvested grain	Size of ranch (Total acres)	Ratio of leased/owned land	Total annual precipitation (inches)
116	0	1760	0	11.45
117	3.61	2767	23.13	16.34
118	0	19200	10.00	13.36
119	20.83	5760	11.11	10.69
120	1.14	4400	15.45	18.50
121	.29	7000	20.57	11.45
122	.19	8320	11.54	17.29
123	3.95	4680	27.35	11.45

\*These numbers are tabulation sheet numbers and not code numbers from the actual schedules.

Appendix Table III. Calculated measures for two groups used in computing discriminant function.

Wheat farms N = 151		Cattle ranches N = 123	
$\Sigma X_{a1}$	348,775.	$\Sigma X_{b1}$	853,283.0
$\bar{X}_{a1}$	2,309.7682	$\bar{X}_{b1}$	6,937.2601
$\Sigma X_{a2}$	6,069.83	$\Sigma X_{b2}$	3,755.23
$\bar{X}_{a2}$	40.197549	$\bar{X}_{b2}$	30.530325
$\Sigma X_{a3}$	2,759.53	$\Sigma X_{b3}$	1,864.65
$\bar{X}_{a3}$	18.275033	$\bar{X}_{b3}$	15.159756
$\Sigma X_{a1}^2$	1,984,335,919.0	$\Sigma X_{b1}^2$	12,780,273,181.0
$\Sigma X_{a1}X_{a2}$	14,766,397.36	$\Sigma X_{b1}X_{b2}$	26,544,513.11
$\Sigma X_{a1}X_{a3}$	6,326,081.69	$\Sigma X_{b1}X_{b3}$	13,141,303.97
$\Sigma X_{a2}^2$	440,049.9113	$\Sigma X_{b2}^2$	201,833.3527
$\Sigma X_{a2}X_{a3}$	110,445.7334	$\Sigma X_{b2}X_{b3}$	56,953.7400
$\Sigma X_{a3}^2$	51,958.3185	$\Sigma X_{b3}^2$	29,581.1799
$d_1 = -4,027.4919$			
$d_2 = 9.667224$			
$d_3 = 3.115277$			

The linear discriminant function for the data in the preceding table is:

$$Z = -0.0000006038637 X_1 + 0.00003860023 X_2 + 0.0011361572 X_3$$

the coefficient of  $X_1$  was reduced to unity, yielding the equation appearing in the text.

Appendix Table IV. Analysis of variance of Z between and within groups.

Source of Variation	D.F.	S.S.	M.S.	F
Within groups	270	.0067069757	.00002484065	
Between groups	<u>.3</u>	<u>.0030491909</u>	<u>.0010163969</u>	40.91667
	273	.0097561666	.00104123755	

Referring to the F table with  $n_1 = 3$  and  $n_2 = 270$ , the function is seen to be highly significant at the .001 level.

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