AN ECONOMIC ANALYSIS OF IRRIGATION IN THE SOURIS RIVER BASIN OF MANITOBA

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by

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ABSTRACT

Economic uncertainty is a major management problem in the agricultural sector. Yield, price and cost variability are some components of economic uncertainty. In the Souris Basin of Manitoba the variability in crop yields have been the major contributing factor to economic uncertainty. In addition, it can be said that in general yields are relatively low. This is a direct result of the general insufficiency of moisture during the growing season and in some years such situations have cumulated into droughts.

This study investigates the economic feasibility of introducing irrigation to the Souris Basin and establishes the optimal farm organizations for selected farm plans. A representative farm was chosen for the Souris Basin for which several hypothetical farm plans were formulated. These facilitated the testing of the various hypotheses which were conceptualized on assumptions relating to the activities to be included, the type of irrigation system and the levels of restraints.

In general it was concluded that irrigation farming in addition to reducing the yield variability which can be attributed to variation in available moisture, will increase farm income above dryland returns. This was based on the assumption that the appropriate irrigation system is used. With respect to the representative farm and its level of resources it was found that the tow-line sprinkler irrigation system returned higher disposable incomes than the self-propelled system did for identical plans. In fact the returns for some plans using a self-propelled system were lower than when the same plans were considered solely for dryland protection. For the plans in which these systems were compared the use of the tow-line system returned disposable incomes

which were $1,335 and $1,492 greater than that obtained from the use of a self-propelled system. Thus within the given framework the tow-line system--which has a lower annual fixed cost and which requires more variable labor and less operating capital than the more automated self-propelled system--is more desirable.

From the activities considered it was established that rapeseed and sunflower were the most profitable alternatives to the present dryland cropping activities--mostly cereal crops. Other special crops such as potatoes and field peas were also profitable but production was constrained by limited markets. The livestock enterprises were the least profitable alternatives. In recommending an optimal farm organization it was shown that production should be diversified and the maximum acreage (168 acres) should be irrigated.

For the dryland programs the optimal solutions generally included the largest acreages of sunflower and rapeseed and smaller amounts of cereal crops. However when irrigation was introduced sunflower constituted the largest fraction of irrigated acreage. Other irrigated crops were alfalfa, potato and field peas. Cereal crops and rapeseed were the main components of the dryland acreage. When only the present dryland crops were considered under irrigation, flax constituted most of the irrigated acreage.

Finally, the demand function for irrigation water was steeply (negatively) sloped indicating that the initial quantity of water used made a large contribution to farm income.

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CHAPTER I

INTRODUCTION

Agriculture is the main-stay of Manitoba's economy. This accounts for the emphasis on research in agriculture and for more efficient utilization of the inputs which go into the production of agricultural commodities. Production decisions are based on marketing conditions, prices of outputs and prices of inputs, attitude of the farm manager and other sociological and economic forces. Thus, there are many restraints to the maximization of farm profit. There might be limitations on the basic inputs such as land, labour and capital. But given these inputs to be relatively fixed (at least in the short run) there are other variables such as insect, diseases, hail, frost and drought with which the farm operator must contend. The yields of the various crops are subject to such stochastic influences such as diseases, hail, frost and drought.

The Problem

In South-west Manitoba insufficient moisture during the growing season has led to lower yields than would normally be expected on such soil types given adequate moisture. In addition to the foregoing, the fluctuations in available moisture from one growing season to the next have resulted in great fluctuations in crop yields over the years. The risk of drought and general insufficiency of plant moisture have comprised one of the foremost production problems facing farm operators in the area.

However, with the knowledge that there is a potential reservoir of underground water in the Souris Basin together with available water from the Souris River and its tributaries, this study attempts to investigate the economic

feasibility of introducing irrigation to the Souris Basin. It is hypothesized that farming will be more profitable under irrigation than under dryland conditions. In addition, the introduction of irrigation will remove the risk of drought and tend to dampen the great variations in yields experienced in the past.

If it can be shown that it is economically feasible to introduce irrigation to the area then this study should proceed to answer the many questions with which farm operators will be confronted. Most of these will concern the viability of the farm firm and the maximization of farm profit.

Farm operators will wish to know what production activities bring in the greatest profits from the available resource. Should production be confined to the cereal crops or should selected speciality crops such as sunflowers and rapeseed be introduced as alternatives? How much more profitable is this latter group of crops? How relevant are these as production alternatives especially in the light of marketable surplus experienced for wheat in recent years? Could farm profits be increased by adding other production alternatives such as potatoes, field peas, forage crops and livestock? If not how important are these for purposes of diversification?

Farm operators' concern is not only focussed on the allocation of scarce resources for the maximiation of farm profit in a given period but also on the expansion and growth of the farming enterprise. Questions are posed as to what resources are most valuable? What happens to farm profits when various levels of available land, labor, capital or even marketing quotas change? What effect will such changes have on optimal farm organizations? What will be the return per dollar invested on the various inputs if additional units are acquired? At what point will diminishing returns set in?

With the introduction of irrigation—a relatively new technology to the Souris Basin—it will be necessary to offer guidance to farm operators. On the basis of the resources they own there are questions as to what type of irrigation system will be most appropriate? How often should crops be irrigated? What level of water application should be used? What crops should be irrigated? If water is priced then farm operators will need to know the value of water to their farm (or demand function for irrigation water). Questions will follow as to how much water is it economical to purchase at various prices?

The answers to these questions constitute some of the knowledge which may be deemed necessary for the efficient management of the farm.

Physical Characteristics of the Souris Basin

The area being studied lies in the south-western portion of the Province of Manitoba. It is the Basin area of that portion of the Souris River which flows in Manitoba. The Souris Basin area occupies portions of crop districts 1, 7, 8 as defined by the Manitoba Department of Agriculture.

The region is located within a radius of 180-200 miles south-west of Winnipeg. However the immediate marketing centre for the region is Brandon which is approximately 20-25 miles north of the Souris River. Most of the livestock are marketed at the packing plant in Brandon. The area is well served by the Canadian National and Canadian Pacific Railways for hauling of its grains. Sunflower seeds can be marketed at Altona where a crushing plant is located.

The Souris River is 450 miles long. It begins in Saskatchewan and flows southerly into North Dakota where it makes a loop. It then flows in a northerly direction entering Manitoba at the south-west portion of the Province. Finally it flows into the Assiniboine River a short distance below Brandon. The main valley of that portion of the Souris River in Manitoba extends for approximately

112 miles. Its watershed varies in topography from hilly and rolling country in the south-eastern portion to rolling and gently sloping land in the central and western portion. Of its 24,600 square miles of drainage area, 3,647 square miles lie in Manitoba.[1]

The region is generally classified as having fertile soils, favourable climate and other physical conditions which are not only suitable for growing crops but also conducive for livestock activities. A survey of the recorded temperatures for the region shows that it possesses the most favourable temperatures for growing crops in Manitoba. The average temperature for the region during the growing season (May to August) is 60.5°F.

In this region the restriction on the number of frost free days can often be a problem. Frost is a more limiting factor in this region than in some of the more northerly parts of Manitoba. Some plants such as vegetable crops are destroyed by the slightest frost whereas others such as rapeseed can better withstand frost. The average number of frost free days recorded at Souris—which is fairly representative of the area, is 107 days, whilst the minimum is 62 days and the maximum is 155 days. Other locations within the area can experience slight variations depending on elevation, topography and the presence of water bodies.

The average annual precipitation for the region is about 17 inches of which approximately 50 percent occurs during the growing season. The estimated annual evaporation is 29 inches. It is thus evident why there exists a moisture deficiency in this region.[2]

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[1] Prairie Water Research Symposium 1; (Agassiz Center for Water Studies, University of Manitoba - May 1968), pp. 3-5.

[2] Ibid.

History of the Water Resource Problem

From a comparison of the annual precipitation and the annual evaporation, it can be seen that moisture shortages can be of concern in such a region which is principally agricultural.

The concern over the shortage of water in the area extends as far back to the years 1930 to 1941 when the area suffered from a serious drought. After the passage of the Prairie Farm Rehabilitation Act of 1935, the building of four dams on the Souris River in Manitoba intensified the water problem. In 1940 the problem having been referred to the International Joint Commission, North Dakota was then supposed to release not less than 20 cubic feet per second during the months of June, July, August, September and October. Reviewing the problem in the late 1950's resulted in modification of the existing order. In times of severe drought when it was impracticable to release the stated volume (20 cubic feet/sec.), the International Souris River Board of Control (established by the International Joint Commission) was to determine the amount of water to be released from North Dakota.[3]

Several schemes to increase the water supply in this watershed have been under consideration. These include the Coulter Dam on the Antler River and storage works on the main stream of the Souris River. Such measures for improving the conservation and distribution of the seasonal flow of water could make a major contribution to the development of irrigated agriculture in the Souris Basin.

Water Potential

In addition to water availability from the Souris River for irrigation,

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[3]Ibid.

one must consider the potential supply of underground water for irrigation of areas which are located away from the natural water course. Studies by the Department of Agricultural Engineering of the University of Manitoba in the Melita area of the Souris River valley have revealed the presence of underground bodies of water-bearing sand and gravel (called acquifers) which seem to have sufficient potential to be of interest for future development.

Studies in the Melita area indicate that there is adequate high quality water to satisfy domestic requirements and to irrigate approximately 50 acres of land on each square mile (640 acres) overlying the acquifer. This estimate is but a conservative one.[4]

It would seem that with proper storage facilities on the main stream and its tributaries and with a good potential of underground water, the assumption to be made in this study re: the availability of water for irrigation, is not an unrealistic one.

Economic Activities in the Souris Basin

The economic activities in the Souris Basin being primarily agricultural are comprised of: cereal crops—wheat, oats, barley, rye; oilseeds—flax, rapeseed, sunflower; specialty crops and forage crops. Livestock also constitute a significant part of the economic activities. Mostly beef cattle, hogs and some sheep are produced in the region.

The importance of the above activities in relation to the total production in Manitoba is shown in Table 1.0. It gives the level of activities

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[4]Prairie Water Research Symposium 1 op. cit., pp. 3-5.

Table 1.0

Economic Activities in the Souris Basin
1961 - 1966

Activities	Unit	% of Manitoba 1961-1966 Ave.	% Change 1961 - 1966
Cattle	No	8.6	10.5
Swine	No	4.95	-19.5
Milk Cows	No	3.75	-30.5
Sheep	No	9.15	-41.5
Hens and Chickens	No	2.4	-38.9
Under Crops	Acres	8.6	15.7
Summerfallow	Acres	10.	-22.1
Pasture	Acres	9.4	32.8
Woodland	Acres	3.4	-

Table 1.1

Distribution of Cultivated Acreage[5] to
Various Crops in the Souris Basin

Crops	% of the Basin 1961-1966 Ave.	% Change 1961-1966
Wheat	44.96	-7.
Oats	15.13	-18.
Barley	6.24	33.
Rye	3.91	21.
Flax	17.67	26.
Rapeseed	.36	637.
Corn Silage	.47	76.
Potatoes	.12	9.

[5]Source: Canada D.B.S., Census of Canada 1961; 1966. Manitoba Agriculture, Catalogue Nos. 96-537, 96-608.

in the Souris Basin as a percentage of all Manitoba. The values indicated are averages from the 1961 and 1966 Census of Canada. Cattle in the Souris Basin made up 8.6 percent of Manitoba's production, whereas hogs and sheep were 4.95 percent and 9.15 percent respectively. Chicken production ranked lowest being only 2.4 percent. For the cropping activities the acreage was 8.6 percent of all Manitoba and summerfallow was 10 percent.

Table 1.0 also shows the relative change in these activities for the Souris Basin from the year 1961 to 1966. The trend has shown an increase in cattle while there were large reductions in hogs, milk cows, sheep and poultry. The acreage under crops has increased by 15.7 percent, while summerfallow decreased by 22.1 percent over the same period.

The percentage of the total cultivated acreage in the Souris Basin which was devoted to the major crops is given in Table 1.1. Wheat occupied the highest percentage (44.96 percent). Oats and flax occupied 15.13 percent and 17.67 percent respectively. The percentage change indicates the trends over the period 1961-1966. Wheat and oats acreages were reduced. Barley, flax, rapeseed, rye and corn silage showed substantial increases.

Recent trends for Manitoba (1969-1970) shows a substantial reduction in wheat and oats acreages. However summerfallow acreage has risen. Barley, rye, flax, rapeseed, sunflower and special crops have also shown increases. It is assumed that in general the Souris Basin will show similar trends.

Objectives

The broad objective to which this thesis addresses itself is the determination of the most efficient economic organization of a representative farm in the area, given various constraints. Consideration does not exclusively embody

farm profit but also the risk element involved in production and possibly marketing. As hypotheses are developed, appropriate organizational farm plans are formulated and analyzed to test these.

The specific objectives of this study are:

(i) To determine the optimal farm organization under the present dryland situation. It is hypothesized that net farm income can be increased by a re-organization of the farm's economic activities.

(ii) To study the effect of introducing rapeseed and sunflowers as alternative enterprises in farm organization under the present dryland conditions. It is thought that these activities can be profitable alternatives to some cereal grains.

(iii) To show what the optimal farm organization is under dryland conditions when oilseeds, other special crops, forage crops and livestock enterprises are added to the present dryland situation. It is hypothesized that the introduction of these activities and in particular livestock can increase net farm income.

(iv) To determine whether it is more profitable to use (a) a self-propelled sprinkler irrigation system or (b) a tow-line sprinkler irrigation system. With the given restraints on capital and labor and in reflection of the acreage to be irrigated, it is hypothesized that a tow-line system is most appropriate for this farming unit.

(v) To determine the optimal farm organization when irrigated activities and dryland activities compete for farm

resources. It is hypothesized that irrigated activities will be more profitable and thus will enter the plan first.

(vi) To compare the net farm incomes generated when the borrowing limits on operating capital are allowed to vary. It is hypothesized that as operating capital is increased so will net farm income.

(vii) It is also hypothesized that when it becomes impossible to acquire additional resources such as land (by renting) or labor (hiring) farm income will decrease.

(viii) To estimate the demand for irrigation water for the representative farm. It is hypothesized that water has some positive value to the economic activities of the farm and thus a demand function for irrigation water can be estimated. Such a function will be negatively sloped.

Methodology

The various hypotheses must be tested. The tool to be used is linear programming. Firstly, this meant the development of a case farm. Census of Canada data and farms in the area provided information on the characteristics of the representative farm.

For the chosen farm a linear programming matrix had to be constructed. This meant decisions as to what activities and restraints must constitute a realistic model. The task which followed involved the estimation of the coefficients and resource restraints for the linear programming matrix.

Having fully constructed the model it was then possible to test the various hypotheses by varying assumptions with respect to activities and resource levels to be included in the various farm plans.

The basis for much of the data on dryland returns was a survey taken for the year 1968 in the Souris and Altona areas. Sixty-nine farmers were interviewed. These were all producers of rapeseed and sunflower, among other crops.

Having looked at the background to the problem and having specified the objectives and methodology in this chapter, the study moves on to Chapter II where some common types of irrigation systems are examined. In Chapter III the theoretical framework for the economic model employed in this study is developed. This leads into Chapter IV which is devoted to the empirical formulation of the linear programming model. Finally the results of the study are analysed in Chapter V and the summary and conclusion given in Chapter VI.

CHAPTER II

IRRIGATION SYSTEMS

Irrigation systems can broadly be classified into the following categories depending on the method by which they may be operated. These are:[1]

(i) surface irrigation systems

(ii) gated pipe irrigation systems

(iii) hand-moved sprinkler irrigation systems

(iv) the mechanical-move sprinklers for example,

the tow-line, boom, wheelmove, self-propelled

A surface irrigation system is one by means of which water is delivered to the cultivated field through siphons flowing out of open ditches. The water flows through the open ditches by gravitational force. It is then distributed from the ditches to the field by siphons. In the case of open fields, borders are used to control the flow of water, whereas for row crops the furrows are used.

With the gated pipe systems water is pumped through a main pipe. Water then flows out of these laterally (through orfices) onto the field. Gravity spreads the water over the field.

The hand-moved irrigation systems are comprised of one main line through which water is pumped. The laterals are made of sections of aluminum pipe each having one or two sprinklers. These laterals are hand moved.

The most common mechanical systems are: (i) the tow-line - where

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[1] North Dakota State University, Department of Agricultural Economics, Bull. No. 474: Irrigation, [W. McMartin and R.O. Bergan], (Fargo, N.D. March, 1968).

laterals are towed from one field to the next by tractor; (ii) boom - which is located on a four-wheel framework and revolves around a central pivot; (iii) the wheel-move system - where laterals are mounted on wheels; (iv) the self-propelled systems which are carried on wheels and revolves around a central pivot point from where the water is delivered. These are all systems which demand less maintenance labor for irrigation than the types mentioned formerly. The time required per irrigation and the irrigated acreage per irrigation will depend on the individual system. The boom system irrigates 1.2-4.0 acres per irrigation whereas the self-propelled system can irrigate an area of radius 1,400 feet per irrigation in a duration of 24-75 hours.

Since both the gated pipe and surface irrigation systems depend on gravity for irrigating there is a tremendous initial cost involved in developing land for irrigation by these systems. In North Dakota land development was averaged at $77.05 per acre.[2] The land must be levelled and in the case of the surface systems ditches and drains must be made. With the sprinkler systems such high initial costs associated with land development are avoided. In South-west Manitoba where cultivated land is relatively flat, sprinkler irrigation systems can be used without any prior land preparation.

Irrigation farming requires more labor per acre than dryland farming. For the gravity systems the input of variable labor per irrigation is much higher than that required by the mechanical systems. Ditches must be cleaned, siphons put into operation and the flow of water controlled. For the mechanical sprinkler systems the greatest amounts of labor are utilized in preparing the

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[2]North Dakota Agricultural Experimental Station, Bulletin No. 404: [L.W. Shaffner] (North Dakota: 1956) p. 9.

system for each irrigation. This involves the movement of pipes from one field to another. As systems become more automated they require more mechanical energy and less farm labor. Thus the tow-line system will require more labor per irrigation than the self-propelled system. The estimated labor requirement for these systems are given in Appendix C.

The introduction of irrigation requires capital investments in wells, machinery and other equipment. For the gravity systems special equipment includes a two-way plow, leveller and ditcher. For the sprinkler irrigation system the costs of motors and pumps, sprinkler systems and pipes are quite high. As would be expected the costs of machinery for the more automated systems are greatest. The costs of the various systems are given in Table 2.0.

Each of these systems has its merits. The gravity systems are labor intensive. They demand a great deal of expenditure on land development but relatively small amounts on machinery. Conversely, the machinery costs for sprinkler irrigation systems are high but land development costs are low.

The choice of any given type of system will depend on the resources of the farming unit and the level of irrigation desired.

Table 2.0

Capital Outlay for Various Types of Irrigation Systems[3]

Type of System	Ave. Acres Irrigated	Range*	
		Lowest	Highest
Tow Line	168	$$3,033	$30,000
Boom	181	2,450	18,340
Wheel-move	141	2,200	23,730
Self-propelled	317	11,350	47,520
Hand-moved	85	3,100	8,791
Gated Pipe	141	3,485	13,522
Other Surface	108	1,163	33,750

*These values are based on the average capacity (acres irrigated) and the source of water. Most mechanical systems used ground water sources whereas surface systems generally used surface water sources.

[3]North Dakota State University, Bul. No. 474, op. cit., p. 23.

CHAPTER III

THEORETICAL FRAMEWORK

The economic model in this study is designed to produce optimal farm organizations, given production resources, restraints and alternative processes available to the case farm. The objective is the maximization of profit using the given resources and restraints. Thus the problem is actually one of resource allocation.

The economic theory relevant to this study is included within the 'theory of the firm'. The resources to be allocated are not only the regular farm inputs such as land, labor, machinery and operating capital but also irrigation input. Because of the emphasis on irrigation in this study, this chapter will examine the theory relevant to the level of irrigation input to be used with other regular farm inputs and the allocation of irrigation water among competing processes.

Under the present dryland production we assume that the regular farm inputs such as land, labor, machinery, fertilizer are combined in optimal proportions. These inputs can thus be considered fixed so as to facilitate the analysis for determining the level to which the irrigation input should be applied.

Figure 3.0 shows a production function and its corresponding total value curve, assuming perfect competition. The production function theoretically, may represent one of the goods produced on the farm. The general form of the function may be given as:

$$Y = f\ (IW/RI)$$

where: Y = Output

IW = Irrigation water - the variables input

RI = Regular farm inputs - the fixed inputs

To achieve economic efficiency, the variable input, IW, should be applied at that level at which the last unit adds to the productive value an amount which equals its cost. This point may be defined when the marginal value productivity of irrigation input in the production of output Y $[MVP_{IW.Y}]$ equals the price of irrigation input (P_{IW}). In figure 3.0 this point is shown by X_1 since,

$$MVP_{IW.Y} = P_{IW}.$$

In terms of the total product curve such a point is reached when,

$$MPP_{IW.Y} = \frac{P_{IW}}{P_y} \qquad \text{(i.e. point } X_1' \text{)}$$

where: $MPP_{IW.Y}$ is the marginal physical product of IW in the production of Y

P_y = Price of output Y

P_{IW} = Price of irrigation water

The marginal physical product is the rate of change in total product with respect to the variable input. Thus for the production function,

$$Y = f\ (IW/RI)$$

$$MPP_{IW.Y} = \frac{dY}{dIW}$$

Similarly,

$$MVP_{IW.Y} = \frac{d}{dIW}\ (TVP)$$

$$= P_y * \frac{dY}{dIW}$$

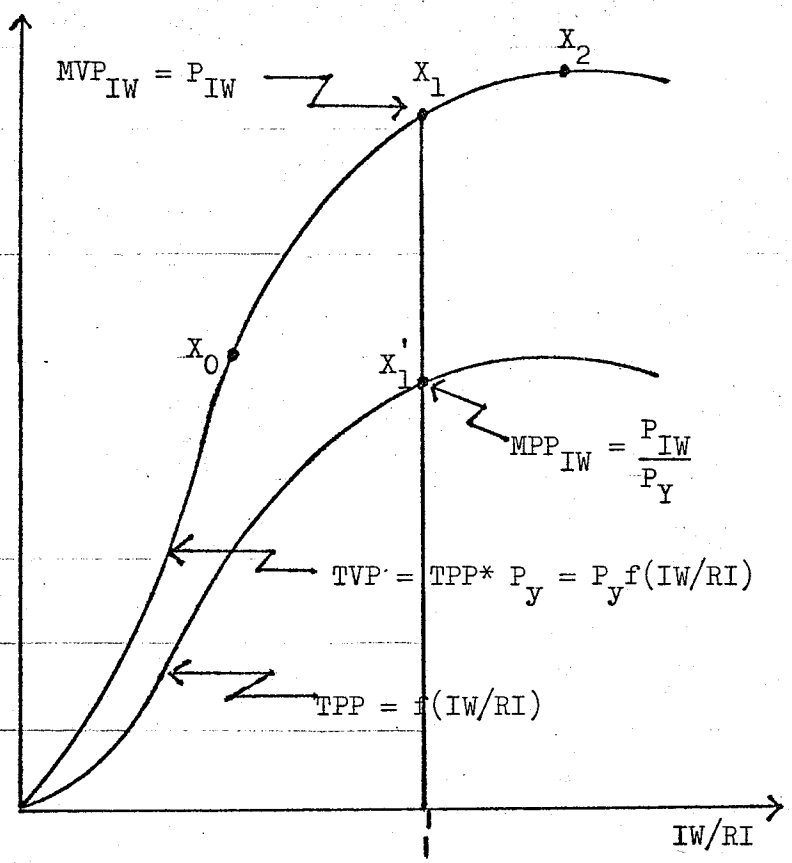

Figure 3.0

The Total Value and Total Product Curves for $Y = f(IW/RI)$

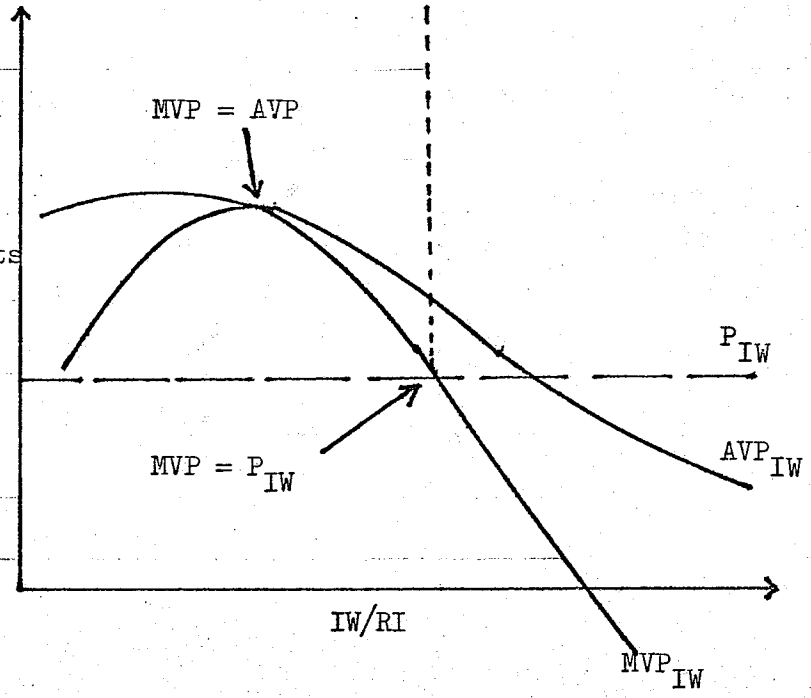

Figure 3.1

Marginal and Average Value Product Curves for the function $Y = f(IW/RI)$

These marginal values for any input level can be represented by the slope of the tangent line to the appropriate function at the chosen input level.

If the $MVP_{IW.Y} > P_{IW}$, for example at point X_o in figure 3.0, then profits can be increased by increasing the level of irrigation input used. The reason being that additional units of the variable input contributes more to the productive value than its cost. Thus profits are maximized when production is carried to a point such as X_1 in Figure 3.0 where $MVP_{IW.Y} = P_{IW}$ or the equivalent point X_1' where

$$MPP_{IW.Y} = \frac{P_{IW}}{P_y} \quad .$$

Increasing the level of irrigation input beyond X_1, say X_2, will add less to the total value of production than the cost of additional units of irrigation input. Thus the rational decision maker should employ X_1 units of irrigation input in order to achieve economic efficiency for the given production function.

For the production function in Figure 3.0 the fixed inputs were assumed to represent the optimal combination which occurs under dryland condition. Experience in irrigating[2] has shown that to maximize profit under irrigation the combination of the regular farm inputs changes from optimal dryland combination. This is a direct result of technological shifts caused by the irrigation input. The addition of irrigation water causes the marginal

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[1] '>' means greater than.

[2] The information gathered resulted from several studies: (1) North Dakota State University, Department of Agricultural Economics, Bul. 474: Irrigation [W. McMartin, R.O. Bergan] (Fargo, N.D. March 1968). (2) North Dakota Agricultural Experimental Station, Bul. 433 [L.W. Schaffner et.al.], (Fargo, N.D., May, 1961). (3) North Dakota Agricultural Experimental Station, North Dakota Agricultural College. Bul. 404 [L.W. Schaffner] (Fargo, North Dakota, 1956).

products of all regular farm inputs to shift. Such shifts will be non-neutral since the optimal combinations of regular farm inputs (RI') will require some inputs such as fertilizer to increase more than others (for example machinery). Thus as irrigation water is increased to its optimal level IW_o in Figure 3.2, the combination of regular farm inputs changesfrom RI to RI_1 to RI_2 . . . to RI'. The corresponding production functions show an upward shift from Y to Y_1 to Y_2 . . . to Y'. Efficient production will no longer take place along the production function $Y = f\ (IW/RI)$ but along the new function $Y' = f\ (IW/RI')$ where the combination of regular farm inputs have changed from RI to RI'.

If we consider the unit of land cultivated as being one acre, then it will be rational to increase the level of fertilizer applied when irrigating beyond that used for dryland production.[3] One reason being that there are more plants and more growth and greater utilization of fertilizer. There are also increases in the amounts of the labor, machinery and operating capital required to cultivate one acre of the specified crop.

As previously defined, profit will be maximized at that input level at which,

$$MPP_{IW} = \frac{P_{IW}}{P_y} \quad .$$

For the production function $Y' = f\ (IW/RI')$ such a point is represented by A in Figure 3.2 and corresponds to IW_o of irrigation water. If the cost of irrigation water was zero, then production would occur at the point at which total product is a maximum (point B) since at this point marginal physical

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[3] North Dakota Agricultural Experimental Station, Bul. 404; op. cit., p. 10.

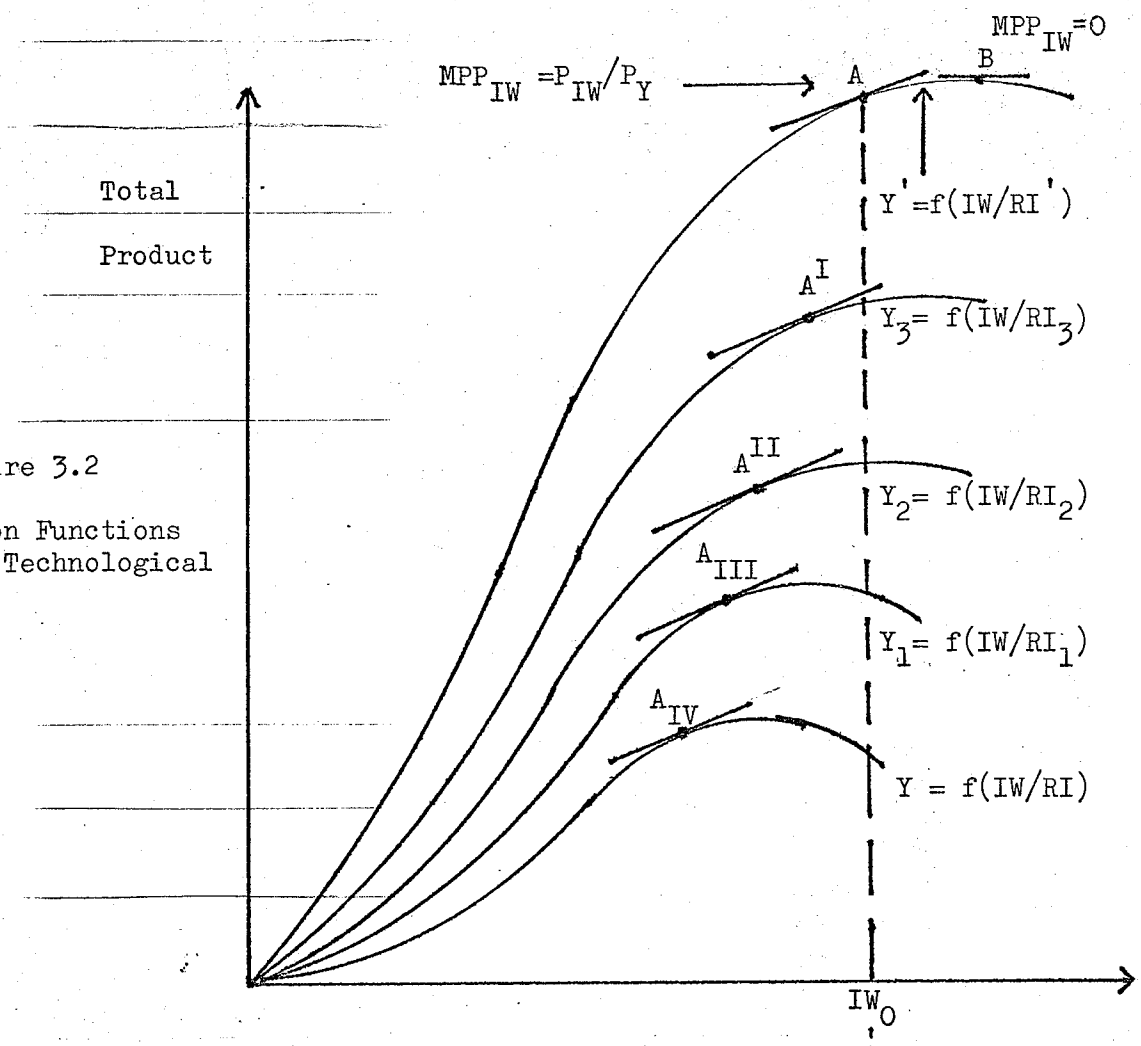

Figure 3.2

Production Functions Showing Technological Shifts.

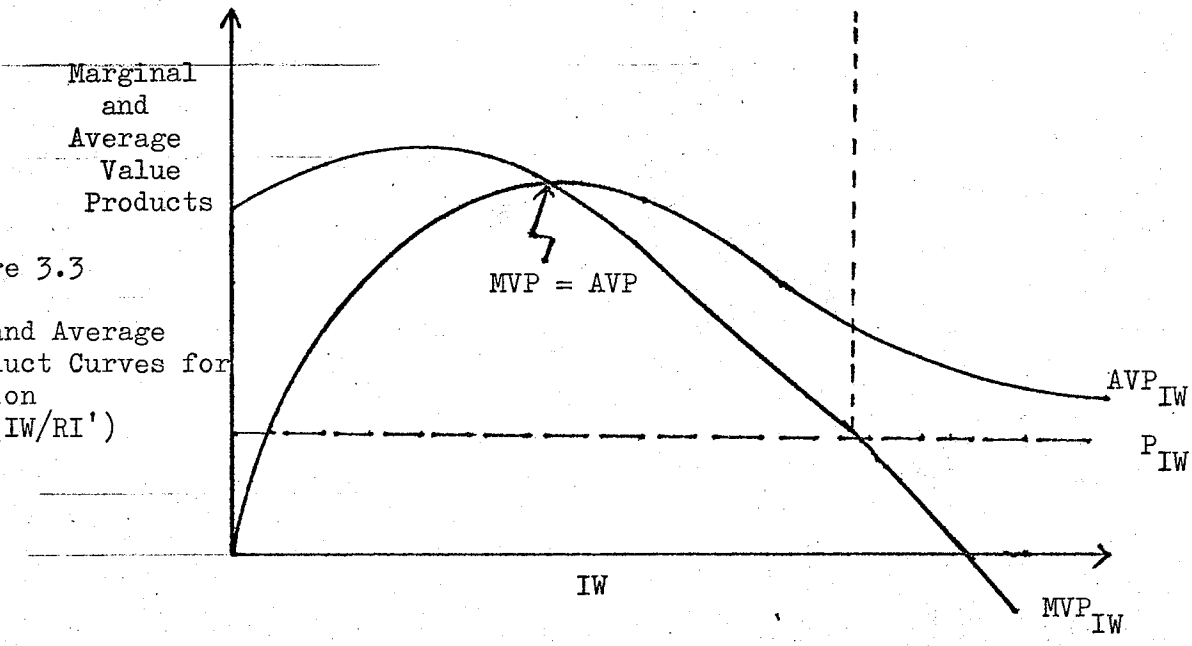

Figure 3.3

Marginal and Average Value Product Curves for the Function Y'= f(IW/RI')

product is zero:

$$MPP_{IW.Y} = \frac{dY}{dIW} = 0 = \frac{P_{IW}}{P_y}$$

When there is some cost in acquiring irrigation input then production will always occur at points where total product is less than the maximum.

In reality the decision maker generally has several input factors which are variable. These are varied to such levels so as to maximize profit. The problem lies in determining the level of each input to be employed in the production of a given output and if several products can be produced the question arises as to how these inputs must be distributed for the production of the various goods.

If it is assumed that there are only two variable factors—for example irrigation water and fertilizer, and one product, then the actual level of each input to be employed so as to maximize profit depends not only on the prices of inputs and the price of the output, but also on the level of physical output forthcoming from the various combinations of these inputs (as given by the production function). In Figure 3.4, irrigation input can be varied along the vertical axis and fertilizer input along the horizontal axis. The locus of points giving combinations of inputs which produce the same level of output are isoquants. These are parallel to each other and may either be convex or concave to the origin. The slope of the isocost lines AB, CD, EF, ... are the negative reciprocal of the input prices. It will be shown why entrepreneurs will substitute one input for another along a given isoquant until the rate of technical substitution (RTS) equals the reciprocal of the input prices. Thus for the isoquant $q^o = f(IW, F)$ where F = fertilizer, q^o is a parameter,

$$dq = \frac{\delta q}{\delta IW} dIW + \frac{\delta q}{\delta F} dF$$

$$0 = MPP_{IW}\, dIW + MPP_{F}\, dF, \quad \text{- since } dq = 0 \text{ for movements along an isoquant}$$

$$\text{And } RTS = \frac{-dIW}{dF} = \frac{MPP_F}{MPP_{IW}}$$

It can be shown that if output is maximized subject to a cost constraint substitution of inputs will take place until,[4]

$$\frac{MPP_F}{MPP_{IW}} = \frac{P_F}{P_{IW}} \qquad \text{. . . . . Eq'n. 3.0}$$

$$\text{or} \quad \frac{MPP_{IW}}{P_{IW}} = \frac{MPP_F}{P_F} \qquad \text{. . . . . Eq'n. 3.1}$$

- that is, the contribution to output of the last dollar expended upon each input must be equal. If any other combination of these inputs are used in the production of a given level of output, then this would not lead to efficient use of resources.

The locus of all tangencies between the isoquants and isocost lines gives the 'expansion path'. Thus the expansion path, OM in Figure 3.4 gives the points of minimum input cost for various output levels.

In situations where the isoquants are concave from the origin as shown in Figure 3.5, corner solutions such as points A, C and E represent minimum cost. Thus the production process should employ only one variable input. The expansion path is collinear with one of the axes.

Since the entrepreneur can vary both the levels of input to be employed in production (cost of production) and the level of goods produced (revenue) then the problem is one of using that input combination at a level which produces an amount of output which will maximize net return or profit.

Referring to Figure 3.4 an entrepreneur would substitute his inputs so

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[4] James M. Henderson and R. E. Quandt, Microeconomic Theory, A Mathematical Approach (New York: McGraw-Hill Book Co., 1958) p. 50.

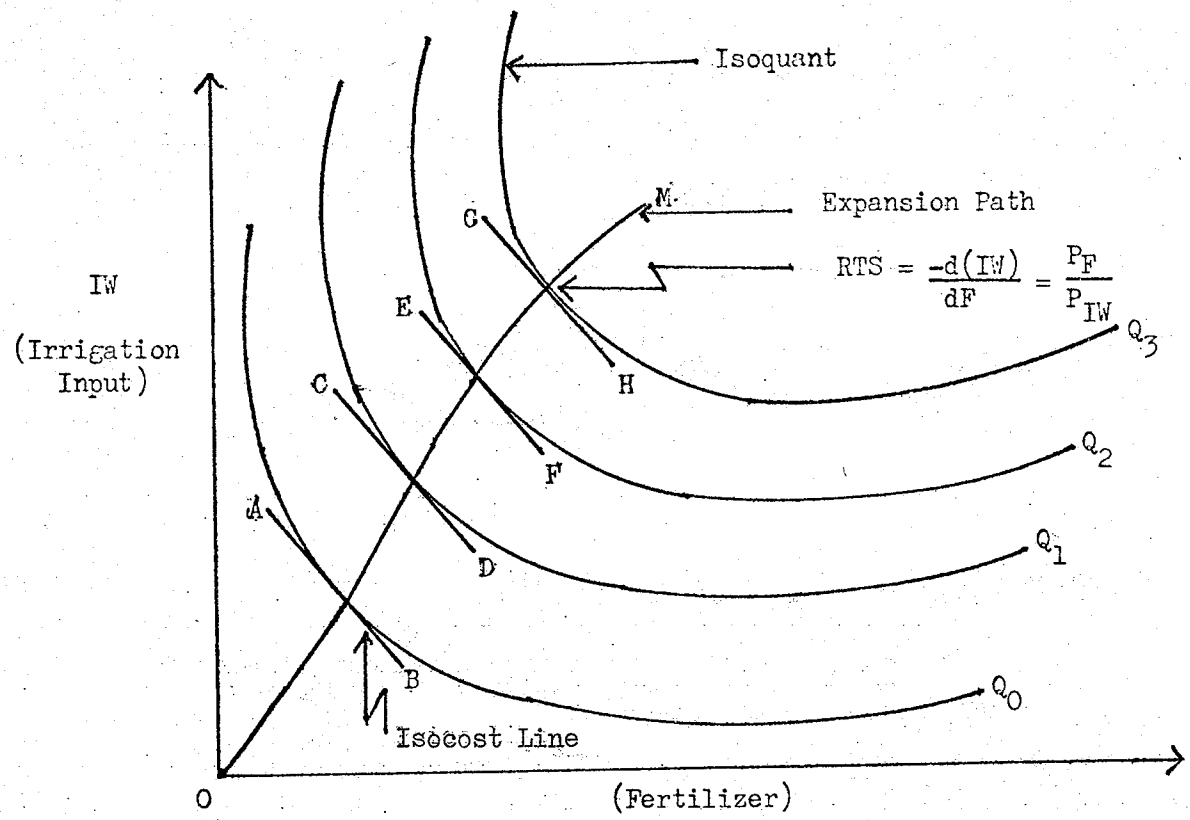

Figure 3.4

The Expansion Path for the Function Y = f(IW, F) -Convex Isoquants

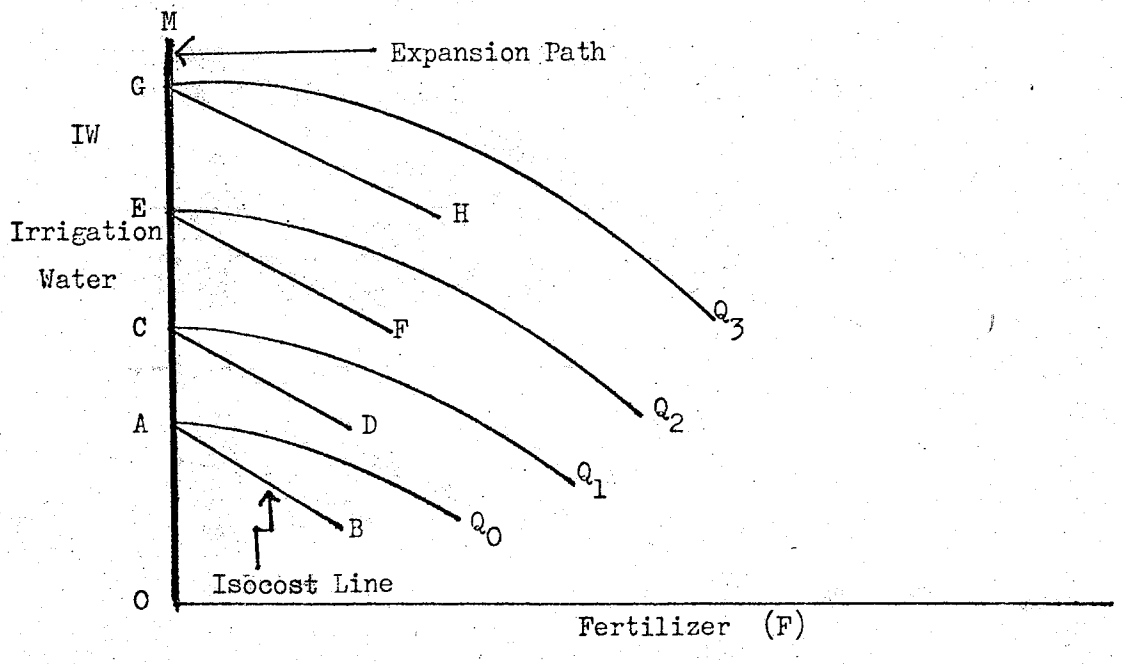

Figure 3.5

The Expansion Path for the Function Y = f(IW, F) - Concave Isoquants

that production will take place on the expansion path. He will then move along his expansion path to that production level (given by the isoquants) which maximizes profit.[5] Thus, given the production function

$$Y = f(IW, F)$$

$$\text{Total Revenue} = P_y(Y)$$

$$\text{Total Cost} = P_{IW}(IW) + P_F(F) + b$$

where P_y, P_{IW}, P_F, F are as previously defined

and b = Fixed cost of production

$$\text{Profit } (\pi) = \text{Total Revenue} - \text{Total Cost}$$

$$= P_y(Y) - [P_{IW}(IW) + P_F(F) + b] \quad \ldots\ldots \text{Eq'n. 3.2}$$

Since it is desired that profit be maximized with respect to the variable inputs, it is thus necessary to solve simultaneously the equations formed from the partial derivates of the profit function with respect to each variable.

Thus since,

$$\pi = P_y f(IW, F) - [P_{IW}(IW) + P_F(F) + b] \quad \ldots\ldots \text{Eq'n. 3.3}$$

$$\frac{\delta \pi}{\delta IW} = P_y f'_{IW} - P_{IW} = 0 \quad \ldots\ldots \text{Eq'n. 3.4}$$

$$\frac{\delta \pi}{\delta F} = P_y f'_F - P_F = 0 \quad \ldots\ldots \text{Eq'n. 3.5}$$

$$P_y f'_{IW} = P_{IW} \quad \ldots\ldots \text{Eq'n. 3.6}$$

$$\text{and } P_y f'_F = P_F \quad \ldots\ldots \text{Eq'n. 3.7}$$

$$\text{or } \frac{P_y f'_{IW}}{P_{IW}} = \frac{P_y f'_F}{P_F} \quad \ldots\ldots \text{Eq'n. 3.8}$$

where f'_{IW} = partial derivate of Y with respect to IW,

f'_F = partial derivate of Y with respect to F

[5] There is no limitation on capital here. However for the case where capital is restrained see reference: Ibid:

From equations 3.6 and 3.7 the first order condition for profit maximization requires that each input be utilized to that point at which the value of its marginal product equals its price.

The second-order condition requires that the principal minors of the relevant Hessian determinant alternate in sign. Thus,

$$\frac{\delta^2\pi}{\delta(IW)^2} < 0 \; ; \quad \text{and} \quad \begin{vmatrix} \delta^2\pi/\delta(IW)^2 & \delta^2\pi/\delta F\delta(IW) \\ \delta^2\pi/\delta F\delta(IW) & \delta^2\pi/\delta F^2 \end{vmatrix} > 0$$

From the above,

$$\delta^2\pi/\delta(IW)^2 < 0 \quad \text{or} \quad P_Y f_{IW}^2 < 0$$

$$\text{and} \quad \delta^2\pi/\delta F^2 < 0 \quad \text{or} \quad P_Y f_F^2 < 0$$

where f_{IW}^2 = Second partial derivate of Y with respect to IW

f_F^2 = Second partial derivate of Y with respect to F

Since P_y is positive, then the second-order conditions require that the marginal products of both irrigation input and fertilizer be decreasing. That is, $f_{IW}^2 < 0$, $f_F^2 < 0$.

The preceding conditions for profit maximization can be extended to the situation where there are 'n' variable inputs $(X_1, \ldots, X_n)$ and 'm' products $(Y_1, \ldots, Y_m)$.

The first-order condition for maximizing profit will require that inputs be used such that their marginal value products, in the production of the same good or many different goods, per dollar be equivalent. Thus,

$$\frac{MVP_{IW.Y_1}}{P_{IW}} = \frac{MVP_{X_1.Y_1}}{P_{X_1}} = \ldots\ldots = \frac{MVP_{X_n.Y_1}}{P_{X_n}} =$$

$$\frac{MVP_{IW.Y_2}}{P_{IW}} = \frac{MVP_{X_1.Y_2}}{P_{X_1}} = \ldots\ldots = \frac{MVP_{X_n.Y_2}}{} = \ldots\ldots$$

$$\ldots\ldots = \frac{MVP_{IW.Y_m}}{P_{IW}} = \frac{MVP_{X_1.Y_m}}{P_{X_1}} = \ldots\ldots = \frac{MVP_{X_n.Y_m}}{P_{X_n}} \quad \ldots\ldots \text{Eq'n. 3.9}$$

where $\frac{MVP_{X_n.Y_m}}{P_{X_n}}$ = Marginal value product of the nth variable in the production of the mth output, divided by the price of input n.

The second-order condition will require that the relevant Hessian determinant alternate in sign.

In actual production practiced farm inputs are generally combined in fixed proportions. Production for a given enterprise does not take place along a smooth continuous production function (Figure 3.0) but at points along a production function. Thus each combination of inputs constitute a process. Figure 3.6 shows several processes. Irrigation water and labor are assumed to be the variable inputs used in the production of corn. The resulting isoquants are discontinuous. Efficiency in production is attained at point E - the tangency of the input price line and the isoquant.

If we assume that two goods are produced then Figure 3.7 shows the production possibility (ABCDE) available to the farming unit. It is comprised of linear segments. These represent the actual restraints on production which are imposed by the farm resources. In such a case revenue is maximized at

production levels where the isorevenue line (given by the price ratio of the outputs) is tangent to the production possibility curve. This is indicated by point C and corresponds to OY of alfalfa and OX of rapeseed.

For the farming unit considered in this study there are a large number of processes and restraints. From the nature of farm production as outlined above the most appropriate tool which can be used in determining the efficient allocation of resources and the various process levels is linear programming. Some discussion will now be focused on this technique.

Linear Programming

There are three quantitative components existent in any linear programming problem. These are an objective, alternative method, activities or processes for attaining the objective and resource or other restrictions which limits the kinds and amounts of processes that can be used in attaining the objective.

The objective varies with the nature of the problem. It may be the minimization of cost or other variables or the maximization of profit as in the present model. A process may be defined as a method whereby resources such as land, labor, fertilizer or other restrictions on planning can be transformed into a product. The production function can be thought of as a tool for exhibiting and comparing different but related processes but "what it fails to present adequately is the consequence of using several processes in parallel and such combinations of processes are characteristic of modern industry".[4]

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[4]Robert Dorfman, Applications of Linear Programming to the Theory of Firm (Berkeley and L.A.; University of California Press, 1951) p. 15.

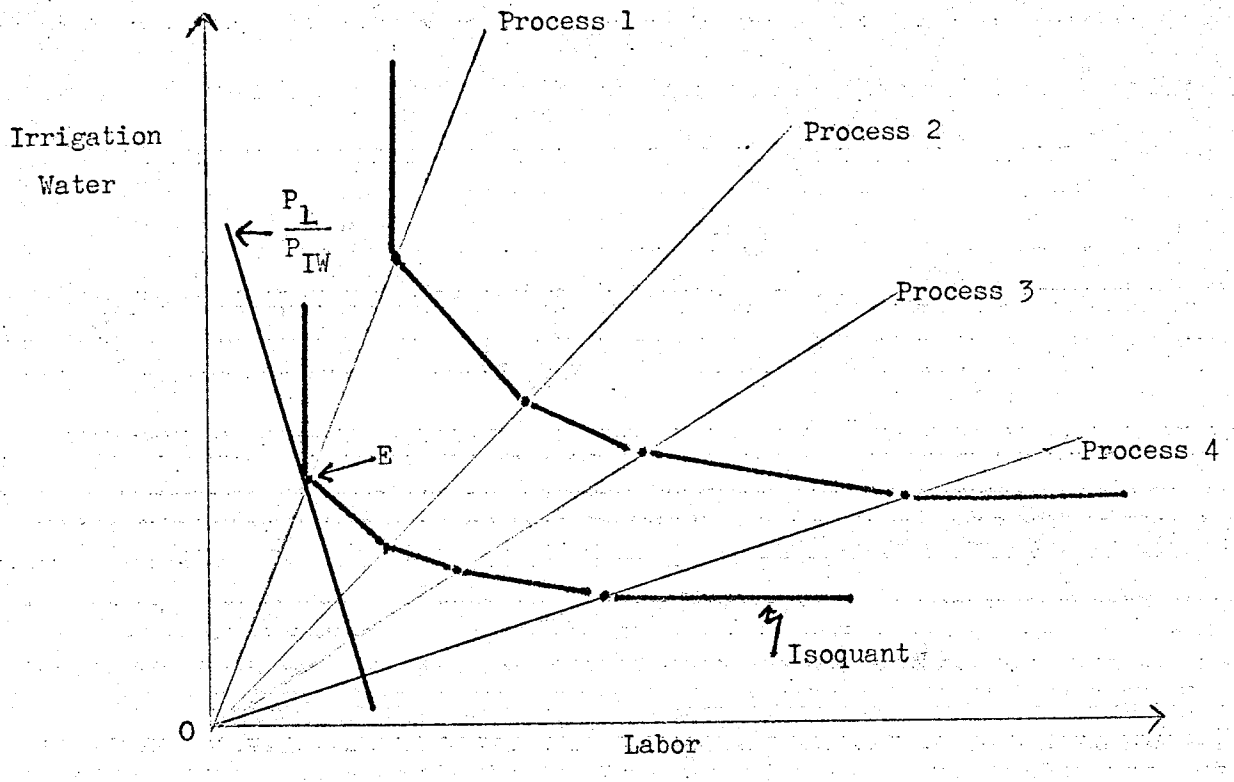

Figure 3.6

Process, Isoquants in Corn Production - Discontinuous Case

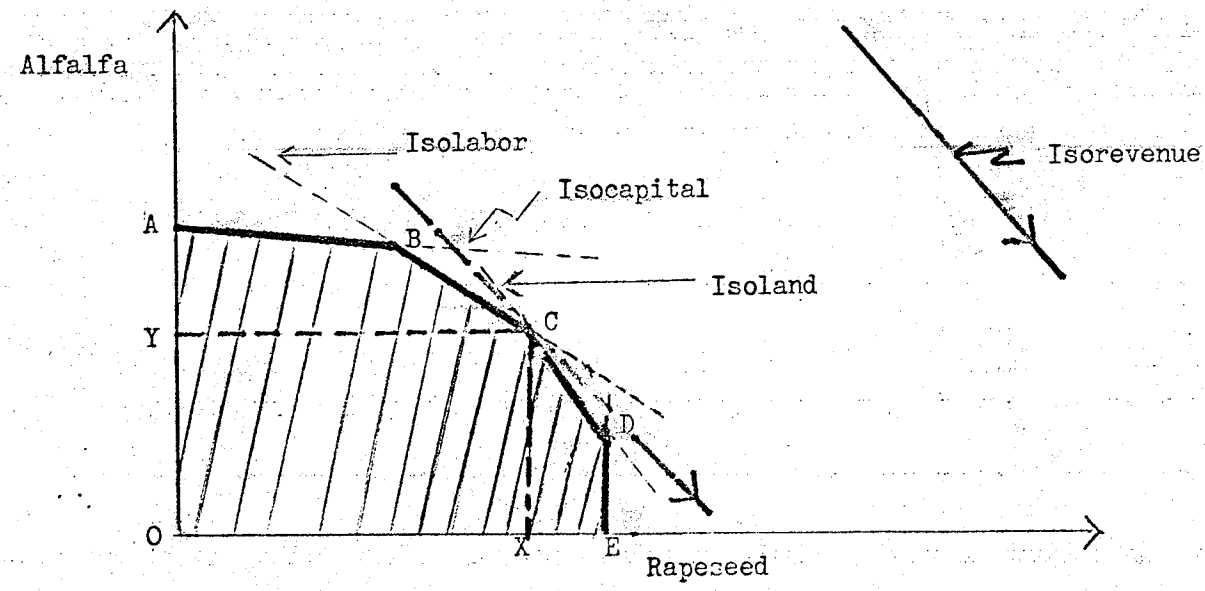

Figure 3.7

Production Possibility Curve for Alfalfa - Rapeseed Processes

Algebraically, the linear programming model used in this study maximizes a linear function subject to a set of linear restrictions. It may be expressed as:

$$\text{Maximize:} \quad Z = \sum_{j=1}^{r} X_j C_j \qquad \text{. . . . Eq'n. 3.10}$$

$$\text{Subject to:} \quad \sum_{j=1}^{r} a_{ij} x_j \leq b_i;\ i = 1, \ldots, n \qquad \text{. . . . Eq'n. 3.11}$$

where Z is the linear profit function which is composed of the sum of all activities multiplied by their net price. Thus x_j is the level of the jth activity and c_j is the net price of the jth activity. In the above formulation there are r real activities. The coefficient a_{ij} is the amount of resource i required to produce one unit of produce j. Thus $a_{ij}x_j$ is the total amount of resource i which goes into the production of activity j. The total amounts of resource i which is used in the production of each of the jth activity is restrained by the level of resource i, given by b_i. Thus there are altogether 'n' such linear restrictions. Finally, a program (which is a combination of activities) constitutes an optimal feasible solution if it is consistent with the restrictions as defined by the linear inequalities and for which no improvement can be made in the objective.

The four major assumptions of linear programming are linearity, additivity and independence, divisibility and finiteness.[5]

The theoretical framework developed in this chapter formed the basis of the economic analysis in this study. Chapter 5 discusses the empirical model.

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[5] E.O. Heady, Linear Programming Methods (Ames, Iowa: The Iowa State Press, 1969) p. 17.

CHAPTER IV

THE ANALYTICAL MODEL FOR THE REPRESENTATIVE FARM

The linear programming model which can be used to test the various hypotheses must relate to a farm which is representative to the Souris Basin. Though the tests are specific and relate to farm organization of the particular farm chosen it is important that results of the analyses should be generally applicable to most farms in the study area. By comparing the resources of a given farm to those of the case farm and from an analysis of the results, the desirable direction of change needed for the given farm should be discerned.

The farms in the Souris Basin[1] were classified according to area. The data used were obtained from the Census of Canada for the years 1961 and 1966. Table 4.0 gives the percentage distribution of farms by size for the region. The greatest percentage of farms fell into the group with areas ranging from 560 acres to 759 acres. On an average for the years 1961 and 1966 this group was comprised of 21.39 percent of all farms in the area. There were 30.62 percent of the farms with an area greater than 759 acres and 47.95 percent less than 560 acres. The representative farm was thus assigned an area of 610 acres. This acreage constituted both improved and unimproved land.

Having chosen the size of the representative farm, the empirical

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[1]The following municipalities were considered as constituting the Souris Basin: (i) Census Division 3 - Riverside, Strathcona
(ii) Census Division 4 - Arthur, Brenda, Cameron, Whitewater
(iii) Census Division 7 - South Cypress, Oakland
(iv) Census Division 8 - Glenwood, Sifton

formulation of its linear programming model was required. The empirical data essential for the completion of the model dealt with resource levels, other restraints on production, the production processes, other activities and finally the input-output coefficients for the linear programming matrix. Each of these components of the model will be discussed in detail.

Table 4.0

Distribution of Farms in the Souris Basin [2]

Size (Acres)	% of Total Farms Ave. - 1961, 1966
0 - 3	.20
4 - 9	.60
10 - 69	1.18
70 - 239	6.43
240 - 399	18.83
400 - 559	20.71
560 - 759	21.39
760 - 1119	16.91
1120 - 1599	10.04
1600 - 2239	2.66
2240 - 2879	.55
2880 and over	.46

[2]Source: Canada Dominion Bureau of Statistics. Census of Canada 1961; - 1966. Manitoba Agriculture, Catalogue Nos. 96-537, 96-608.

Farm Resources

The resources of the farm are actually the ingredients of production. When a production process is increased, one or more of these resources are utilized thus decreasing their supplies. The resources of the farm therefore impose some of the restraints on production. The major resources of the farm can broadly be classified as land, labor and capital.

Land. As mentioned previously the acreage assigned to the case farm is 610 acres of which 570 acres are improved while the remaining 40 acres were comprised of unimproved land, roads, farmstead and other buildings. Of the improved acreage, 140 acres[3] were put into summerfallow annually with 430 acres remaining as the acreage of stubbleland and the previous year's fallowland. When irrigation is introduced a maximum of 168 acres of stubbleland can be used as the land supply for irrigated cultivation.[4] The remaining acreage of stubble and fallow constitutes the land supply for dryland production. Table 4.1 gives the resource restrictions for the empirical model.

Labor. The supply of labor is an important restriction on the production processes of the model. Labor supply is comprised of operator's labor and family labor. For the production period considered (one year) it is estimated that the operator contributes a total of 225 working days. Family labor amounted to 187 days. The seasonal distribution of labor is given in Table 4.1. The total amount of labor available for production is 3900 hours.

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[3]Summerfallow was assumed to constitute approximately 25 percent of the total improved acreage.

[4]The upper limit for irrigated acreage was set at 168 acres for two reasons: (i) the limitation on availability of water and (ii) experiences in North Dakota indicate that 168 acres is the average capacity of the tow-line system.

Table 4.1

Resource Supply for the Representative Farm

Resources	Unit	Level
Land:		
Total Land	Acres	610
Unimproved	"	40
Improved	"	570
Total Stubble	"	430
Fallow	"	140
Labor:		
Operator's (Supervisory)	Hours	1,125
Total Family and Operator's	"	3,900
Spring Labor	"	700
Summer Labor	"	1,000
Fall Labor	"	800
October Labor	"	520
Winter Labor	"	880
Capital: (Operating)	$	4,000

In addition to the above, it is estimated that the operator could provide an additional 1,125 hours for supervising production on the farm. In many cases it is possible for the operator to be engaged in production while supervising at the same time.

Capital. The level of cash operating capital owned by the farm operator is averaged at $4,000. This is essentially designed to accommodate the variable cost of production and thus will not be used for longer-term investments such as feedlots and irrigation equipment.

The above are basically the resources which are relevant to the model. Some of these restraints have been made less restrictive by the introduction of processes which are capable of increasing their levels providing there is some net contribution to farm income. These will be discussed further under the next section.

In addition to resource restraints used in the linear programming matrix, the implicit assumption is made that the farm operator has the necessary machinery complement to carry out production. From discussions with some farmers in the area, it is felt that the above assumption would generally hold true. In many cases operators indicated that they presently had excess machine capacity which could be used in cultivating additional acreages. However when irrigating and raising livestock capital investments must be made on irrigation equipment and a livestock feedlot.

Activities

In a linear programming matrix the resources or restraints occupy the rows whereas the processes or activities are shown in the columns (Appendix E). The elements corresponding to a given column and a row, when

positive, indicate the amount of a resource which is used when the process is increased by one unit or when negative, it indicates how much is added to the level of the particular restraint or resource for a similar increase in the activity. Thus typically, an oat producing activity will indicate the amount of land, labor and capital which is used when one acre of oat is produced. The corresponding cells in the matrix are filled with positive coefficients. It also increases the supply of oat (shown by a negative coefficient) by the yield resulting from one acre and decreases the maximum acreage restraint for wheat by one acre. Normally such an activity contributes a negative quantity to the objective function. This quantity is the actual cost of production (excluding the cost of land, farm labor) for oats. In the present model, the oat producing activity contributes zero to the objective function and a positive quantity, which equals production costs, to both the 'cash generated' row and the 'income accounting equality' row.

The net contributions of all activities to the objective function are thus entered in the 'cash generated' and 'income accounting' rows. The latter entry facilitates the introduction of activities which deduct income tax from the net income. This is demonstrated in the matrix in Appendix E.

Cropping Activities. The production activities are comprised of cropping activities and livestock activities. The crops considered for production are wheat, oats, barley, flax, rye, rapeseed, sunflower, potatoes, field peas, corn, alfalfa and forage grass. These are all considered for dryland production.

All crops but rye are used as alternative enterprises in irrigated production. There are 26 dryland cropping activities and 12 irrigated activities. Sugar beets were not considered for production for two reasons. Firstly, sugar beet is grown only on contracted acreages which tend to be distributed closer

to the sugar beet plant in Winnipeg. Secondly, it is estimated that the high transportation cost from the Souris Basin to Winnipeg makes sugar beet production non-economical.

The cropping activities for those crops which are not used as feed, for example potato and rapeseed, made provision for marketing the produce directly within the same activity. However, those produce which can be used as livestock feed and/or marketed through selling activities have been transferred from their respective production activities by supply transfer rows. These products are oats, barley, wheat, alfalfa, grain corn and rye. There are two selling activities for wheat—one of these provides for sales within the given quota whereas the other accounts for the sale of wheat outside the quota as a feed.

Since forage grass and corn silage are produced solely for the beef enterprises on the farm, there are no selling activities for these.

The operating cash owned by the farm operator can possibly limit crop production appreciably. Thus the model includes an activity which allows short-term capital to be borrowed for crop production. The amount which can be borrowed in the various plans is limited.

Livestock Activities. There are altogether four livestock activities considered. One of these is a feeder-calf enterprise. The steers are purchased at a weight of 400 pounds in the fall. They are then fed for an average of 220 days to a weight of 950 pounds at which time they are marketed. The remaining two beef enterprises are identical. One starts in the fall whilst the other starts in early spring. For these enterprises, yearling steers at an average weight of 750 pounds are purchased. They are fed for an average of 107 days to

a marketable weight of 1,050 pounds.

The hog activity is a feeder hog enterprise. This activity is allowed for the winter months when the demand for farm labor is not as great as in summer. The feeders are bought at a weight of 25 - 40 pounds and marketed at an age of 160 - 165 days at a body weight of 200 pounds. The carcass weight marketed is given as 150 pounds. Estimates on the operating costs for the various livestock activities are given in Appendix D.

The grains which are required for feeding livestock come from produce supplies which are created by the grain producing activities. Other feed requirements such as molasses and urea are bought whenever required. It is also possible to purchase additional oats and barley for feeding livestock.

The purchase of winter livestock and the operating cost for these activities are provided for with capital borrowed for livestock production. There is an upper limit on the amount which can be borrowed. When winter livestock is marketed, the returns are placed into a supply restraint. This provides capital which can be used for purchasing and producing summer feeders. Only at the end of the production period will the sum borrowed for livestock production plus an annual interest charge of 8 percent be repaid.

A least-cost ration was developed for the beef-cattle enterprises. The ration is specified in terms of the net energy required for maintenance (NEM) and the net energy required for production (NEP) in order to achieve the desired feed conversion ratio. Each of the feeds had to be expressed in terms of NEM and NEP equivalents. Thus there are 16 activities associated with the feed for each of the calf and yearling feeder enterprise. Eight of these change the feed grains and forage into NEM equivalents and eight into NEP equivalents.

The case farm had no provision for a beef enterprise. It was necessary to construct a feedlot the costs of which is given in Appendix D. This provides accommodation for 50 head of beef cattle throughout the year. An activity for the construction of such a feedlot was introduced. Here the cost shown is the annual fixed cost. It was estimated that existing building space can provide accommodation for 50 feeder hogs.

Irrigation Activities. For this model there are two types of irrigation systems considered. These are the tow-line system and the self-propelled sprinkler system. The purchase of either system can be financed by means of long-term loans from Farm Credit Corporation (F.C.C.) or any other farm financing agency. When a system is acquired the model accounts for this by an activity which charges the fixed cost or annual payment (depreciation plus interest) for the given system. The activity which levies the fixed cost also includes the fixed quantity of labor which is required annually for setting up and putting away the irrigation system.

The manner in which fixed costs are paid can affect the solutions for the various plans significantly. If all fixed costs are paid with the use of operating capital, then production can be unduly restrained. In this model payments of fixed costs are made at the end of the production year. Thus fixed costs are deducted from the income which is generated rather than from the operating capital. Similar payments for the construction of a feedlot, hydro bill, telephone and taxes are taken out of the income generated.

Associated with each system are four activities--a spring-irrigation activity, a summer-irrigation activity, a fall-irrigation activity and an activity for the pumping of irrigation water. The last of the above shows the

level of operating capital required when one acre-inch of water is pumped. This operating expense represents the cost of energy. The irrigating activities are brought into the solution each time it is required to irrigate at any of the three periods of the growing season. Each activity gives the labor and variable cost required per irrigation.

Other Activities. In addition to the activities mentioned above there are other activities which are important to the model. The model includes 4 activities which make it possible to hire seasonal labor. Table 4.2 shows the upper limits on the amounts which can be hired. The restraint on the available labor was made more flexible by the introduction of such activities. There is also an activity allowing for the rental of stubble land to a maximum of 160 acres.

The model also makes provision for marketing quota restraints which are imposed on the sale of wheat, oats, barley, rye, flax and rapeseed. All crops (including summerfallow and perennial forage) considered in this study contribute towards the assignable acreage. The solution to the linear programming matrix assures that these assignable acreages are distributed among the crops in such a way so as to maximize net returns. Thus, as the various cropping activities are brought into the solution they add to the assignable acreage supply. For each of the crops mentioned above, there are quota transfer activities. Each of these can transform an assignable acre (removed from the assignable acreage supply) into bushel quotas (for the specified grain) which is then placed in the appropriate bushel quota restraint. Thus for a grain to be marketed its quota supply must be increased. This can only be done by assigning acreages to the given crop. The delivery quotas used are given in Table 4.3.

Table 4.2

Available Seasonal Labor For Hire

Type of Labor	Maximum Amount Which Can Be Hired (Hrs.)
Spring Labor	300
Summer Labor	400
Fall Labor	300
October Labor	220

Table 4.3

Marketing Quotas For The Various Crops

Crops	Quotas (Bu./Acre)
Wheat	8
Oats	20
Barley	30
Rye	20
Flaxseed	12
Rapeseed	40

These are the final quotas for the 1970-71 crop year as given by the Canadian Wheat Board.

In order to estimate disposable income thirteen income tax activities are included. These are shown in the matrix in Appendix E. The level of personal exemptions is calculated on the basis of the assumption that the farm family is comprised of the farm operator, his wife and two children. The estimated tax on various levels of net income is given in Appendix A.

For each income tax activity, the coefficient entered in the 'cash generated' row is the income tax which will be payable assuming that the income generated is that value entered in the 'income accounting equality' row. The value '1' entered in the 'accounting equality' row ensures that the appropriate level of tax is levied.

After income is deducted from the cash generated a cash transfer activity transfers the remaining cash to the objective. Thus the value of the objective is the maximized disposable income.

Other Restraints

Many restraints other than land, labor and capital are included to make the model realistic. Quota restraints have already been mentioned. In addition, there are maximum acreage allotments for the various crops. Even though a particular crop may be most profitable the amount of acres cultivated in that crop will be limited. This is so since farm operators tend to diversify production, maintain soil condition, reduce disease and insect opportunities.

Coefficients

The coefficients used in this model were derived from various sources.

Firstly, the cost of production estimates and the seasonal labor requirement for both dryland and irrigated cropping activities are developed in Appendix B. An unpublished 'Handbook on Input-output Data for Crop and Livestock Production in Manitoba' by John Nicolson provided information on the times requires to complete the various tillage operations on one acre of land in the Souris Basin. Using this information and information on the tillage practice, total machine time, total machine cost and seasonal labor required to cultivate an acre of the various crops were estimated. Appendix Tables B-8 and B-9 summarize the costs of production. Labor requirements per acre are given in Tables B-10 and B-11.

For the irrigated crops, estimates had to be made on the level of irrigation water required per acre and also on the number of irrigations required seasonally. These are given in Appendix C. The fixed annual cost for each irrigation system, the fixed amount of labor required annually in setting up and putting away each system, the variable cost and labor per irrigation and the variable cost of pumping an acre-inch of water are all shown. The basis for the latter group of coefficients was bulletin 474[5] (North Dakota State University) where experiences with respect to cost and labor requirements of the various irrigation systems used in North Dakota are summarized.

Since the irrigated acreage in the Souris Basin is rather small, the available data from the area on irrigated yields are confined to experimental trials at Melita by R. Filteau, the agricultural representative in the

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[5]North Dakota State University, Department of Agricultural Economics, Bul. 474: Irrigation, [W. McMartin, R.O. Bergan], (Fargo, N.D. March 1968) p. 34.

area. Yields are available for corn, alfalfa and potato. It was thus necessary to obtain estimates on yields from existing irrigation projects outside of the study area. The projects chosen are the South Saskatchewan Irrigation Project at Outlook, Saskatchewan and the Lower Yellowstone Irrigation Project located in South-west North Dakota and Dawson and Richland counties in Montana. These projects were chosen for the following reasons:

(i) though drier than the Souris Basin, generally their climatic conditions are similar

(ii) their soils are similar to that found in the Souris Basin being well drained and porous and well suited to irrigation.

With such similarities it is hoped that irrigated yields should approximate expected yields under irrigation in the Souris Basin. For some crops, the yields used were adjusted values.

Most of the dryland yields for cereal crops were obtained from the survey[6] data. These had to be adjusted for fertilized, unfertilized, stubble and fallow conditions. Yields for forage crops and some special crops were taken from the returns given for dryland production from surveyed farms in North Dakota.[7]

The input-output coefficients for livestock activities are estimated

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[6]This survey constituted one part of the present study. It was taken in South and South-west Manitoba and was designed to estimate costs and returns for crops--particularly rapeseed and sunflower.

[7]North Dakota Agricultural Experimental Station, Bul. No. 433: Integrating Irrigation with Dryland Farming, [L.W. Schaffner et.al.], (Fargo, N.D., May 1961) Appendix Tables 1, 2.

in Appendix D. As indicated previously, studies by the Manitoba Department of Agriculture provided most of the information.

Because of the fluctuations of product prices according to market conditions, the prices used were the averages for a three year period (1967-1969). Such an average value, it was assumed, would be of a more stable nature.

Analytical Plans

In order to test the various hypotheses of this study it was necessary to formulate analytical plans for the linear programming model developed. There are sixteen plans which were formulated. These were obtained by making specific assumptions as to the activities which must be included in the model for the representative farm. Assumptions were also made with respect to the type of irrigation system used and the levels of various restraints.

The first five plans considered are for dryland production activities whereas the remainder includes both dryland and irrigated production activities. The levels and distribution of farm-owned resources remain as indicated in Table 4.1 for all plans unless stated otherwise. The limits on seasonal labor which could be hired (Table 4.2) and on the available land for rent remain unchanged unless specified otherwise. The maximum acreage restraint for the various crops and the delivery quotas remain constant for all plans. The plans considered (Table 4.4) were:

Plan 1: This plan is essentially representative of the present dryland activities for the representative farm. This included the following dryland crops - wheat, oats, barley, rye and flax. No livestock activities were introduced. The activities considered included production on both fallow and stubble land. The borrowing limit on operating capital for crop production was set at $6,000.

Plan 2: This plan is the same as Plan 1 except that two rapeseed and one sunflower producing activities were added.

Plan 3: Plan 3 introduces dryland activities for producing potato, alfalfa, field peas and grain corn. These were included with the activities of Plan 2.

Plan 4: This plan combines the present dryland activities, as given in Plan 1, with four livestock activities plus the growing of grain-corn, corn silage, alfalfa and forage grass. The livestock activities are as follows: 1 calf-feeder enterprise, 2 yearling feeder enterprises and 1 hog-feeder enterprise. The borrowing limits on crop operating and livestock operating capital are $6,000 and $10,000 respectively. It was assumed that for this plan there were no markets for grain corn or alfalfa.

Plan 5: This plan includes all cropping activities, as given in Plan 3, together with the four livestock activities and forage crops. The borrowing limits on operating capital remain the same as in Plan 4.

Plan 6: In this plan the borrowing limit for crop operating capital is decreased from $6,000 to $4,000. In this plan almost all the present dryland crops are cultivated under both dry and irrigated conditions. The exception being rye which is only grown under dryland conditions. For this plan a tow-line irrigation system is used.

Plan 7: This plan is the same as Plan 6 except that the borrowing limit on crop operating capital was increased to $6,000.

Plan 8: In this plan the activities are those in Plan 7 together with dry and irrigated rapeseed and sunflower. The borrowing limit remains the same.

Plan 9: Plan 9 is the same as Plan 8 but includes livestock, forage and special crops which are grown under both dryland and irrigation. The borrowing limit on crop operating capital remains at $6,000 whilst that for livestock is $10,000.

Plan 10: This plan is identical with Plan 9 except that a self-propelled irrigation system is used in place of a tow-line system.

Plan 11: This is the same as Plan 8 except for a change from a tow-line to a self-propelled irrigation system.

Plan 12: This plan considers dry and irrigated cereal, alfalfa, grain corn, silage corn and forage. However there is no market available for alfalfa, corn and forage. The four livestock activities are also considered and a tow-line irrigation system used. The borrowing limits on crop operating capital and livestock operating capital are $6,000 and $10,000 respectively.

Plan 13: This plan contains the same activities and resources as Plan 9, except that no land is available for rent.

Plan 14: The borrowing limits on crop operating capital and livestock operating capital are both $8,000. The activities and other resources are as in Plan 9.

Plan 15: This plan is the same as Plan 9 except that no spring, fall or October labor is available for hire.

Plan 16: Plan 16 includes a water supply restraint. The activities are the same as for Plan 9. The water supply is increased from zero by increments. The objective being to find the marginal value product of various quantities of water and to determine the levels at which the marginal value

Table 4.4

Composition of the Various Analytical Farm Plans

Activities / Plans	Dryland Production						Irrigated Production				Oper. Cap. (Crops) $	Oper. Cap. (LVSTK) $	Irrigation System	Other
	Cereals and Flax	Rapeseed and Sunflower	Potatoes Field Peas	Forage Grass Silage Corn Livestock	Alfalfa	Grain Corn	Cereals (except rye) & Flax	Rapeseed and Sunflower	Alfalfa Grain Corn Silage Corn	Potato Field Peas				
1	X										6,000			
2	X	X									6,000			
3	X	X	X		X	X					6,000			
4	X			X	X	X					6,000	10,000		No Market for Alfalfa, Grain Corn
5	X	X	X	X	X	X					6,000	10,000		
6	X						X				4,000		Tow-Line	
7	X						X				6,000		Tow-Line	
8	X	X					X	X			6,000		Tow-Line	
9	X	X	X	X	X	X	X	X	X	X	6,000	10,000	Tow-Line	
10	X	X	X	X	X	X	X	X	X	X	6,000	10,000	Self-Prop.	
11	X	X					X	X			6,000		Self-Prop.	
12	X			X	X	X	X		X		6,000	10,000	Tow-Line	No Market for Alfalfa, Grain Corn
13	X	X	X	X	X	X	X	X	X	X	6,000	10,000	Tow-Line	No Land for Rent
14	X	X	X	X	X	X	X	X	X	X	8,000	8,000	Tow-Line	
15	X	X	X	X	X	X	X	X	X	X	6,000	10,000	Tow-Line	Only Summer Labor Avail. for Hire
16	X	X	X	X	X	X	X	X	X	X	6,000	10,000	Tow-Line	

product changes. The process stops when the marginal value product of water reduces to zero.

The above sixteen plans were analysed and the results are presented in Chapter V.

CHAPTER V

EMPIRICAL RESULTS AND INTERPRETATIONS

The analysis is based on the assumption that the prime objective of the farm operator is to maximize his net return for the single production period considered. The focus is static and short-term since the programming model used is monoperiodic. The farm operator is thus working with many constraints such as limited resources, managerial ability and marketing limitations and within such a framework he will be confronted with the question as to how his farm should be organized so as to mazimize his net return for the production period.

Prices of farm inputs and outputs change over time and consequently the corresponding disposable incomes of the various plans will change. However, if all prices exhibit similar movement over time, then the farm organization of each plan remains unchanged. Thus the optimal farm organizations, which are given in the solutions of the analytical plans, constitute the more useful part of the results. These can guide farm operators in future production periods.

The validity of these results as a guide to any farm operator in helping him decide on the optimal farm organization for his farm will depend on the following:

(1) how close the input-output relationships for his production processes are to those used in the model. This to a large extent depends on his managerial efficiency.

(2) how much the price relationships have changed from those in the model.

(3) how close the levels of his farm resources are to those used for the representative farm. This would also include a comparison of marketing quota restrictions and other restraints.

Though the model is monoperiodic it is nonetheless important that some attempt be made to interpret and discuss the results within the framework of a longer planning period (probably a few years). This is especially relevant when considering the fact that irrigation is not only used as an input to increase income for any given year but it can also contribute to income stability over a number of years. This has implications when considering the growth of the farm firm--a consideration with which the farm operator should be concerned.

Before discussing the results it would be beneficial to elaborate on the meaning and implications of some expressions which are used in the discussion of the results which follows in the rest of the chapter.

The optimal farm organization for the various plans indicate the levels of dryland crops, irrigated crops and livestock activities which are required so as to maximize farm income for each plan. The amounts of the cropping activities are indicated by the acreages. The level of livestock activities is referred to by the number of animals.

On the basis of the prices assumed and the corresponding physical (input-output) relationships for each activity the objective function for each plan generated an estimated maximum disposable income. This represents the returns to land, labor (family and operator's) and capital.

Production on the farm is restrained by resources, among other things. It is of interest to the farm operator to know what farm resources impose the greatest restrictions on production. Of even greater benefit to a farm operator is to have these limiting resources quantified in terms of the actual value of an additional unit to the whole plan. Such values are given by the marginal value products. If an additional unit acquired can contribute more to farm revenue than its cost, then if possible it should be obtained and used in production. The marginal values of the limiting resources thus indicate the direction in which it is most profitable to expand farm production for any given plan. From a growth concept for the farm firm these will suggest possible strategies.

Interpretation of Results

The optimal solutions of the various plans were examined so as to discern the effects of various assumptions on farm organization and disposable income. The section which follows attempts to answer specific questions such as: what effects does the level of available land, labor and capital have on income and farm organization? What degree of restriction on production is imposed by the marketing quotas? What irrigation system adds most to farm profit? What are the effects of various activities on farm organization and income? What is the nature of the farm's demand function for irrigation water?

Effect of changes in available capital. Though the level of cash operating capital was constant for all plans, the restraint on capital use was imposed by borrowing limits. It was hypothesized that cropping activities are more profitable than livestock activities and thus if allowed

to compete for capital, livestock may not enter the solution. Since it was desirable to include livestock in the optimal farm plans for the purpose of diversification, there was a separate capital supply restraint for livestock.

The foregoing hypothesis on the competitive use of borrowed capital is supported by the results of Plans 9 and 15 given in Table 5.0. In Plan 9 the borrowing limits on capital for crops and livestock were $6,000 and $10,000 respectively. In Plan 15 cropping activities were allowed an additional $2,000 whereas the limit for livestock activities was reduced by $2,000. The shift in available capital from livestock to crops caused an increase in disposable income from $11,962 for Plan 9 to $12,162 for Plan 15. The above results indicate that the return per dollar invested in crops is generally greater than that obtained from livestock investments. If allowed to compete for capital, the cropping activities will enter the optimal solution before livestock.

As greater amounts of capital are available, it will be possible to acquire more of the scarce resources such as land and labor to limiting amounts. Thus greater amounts of capital should facilitate greater production and a higher disposable income can thus be generated. This was demonstrated in Table 5.1. The limit on capital which could be borrowed for crop production was increased from $4,000 in Plan 6 to $6,000 in Plan 7. Both of these plans contained the same activities (dry and irrigated cereal) yet the disposable income rose from $4,621 in Plan 6 to $4,714 in Plan 7.

In Plan 6 the marginal value product (MVP) of capital was $.25. When the limit on borrowed capital was increased by $2,000 in Plan 7 the MVP

Table 5.0

Effect of a Shift of Borrowed Capital - From Livestock to Crops - on Disposable Income

Plan	Activities in Plan	Bor. Limit Crop Oper. Capital	Bor. Limit Lvstock Oper. Capital	Disposable Income	Optimal Farm Organization					
					Dryland Activities (Acres)		Irrigation Activities (Acres)		Livestock (No.)	
9	-all dry and irrigated cropping activities	$6,000	$10,000	$11,962	Wheat	(F) 22	Sunflower	84	Feeder Calves	50
					Rye	(S) 88	Potatoes	12	Feeder Hogs	20
					Rape	(FF)118	Field Peas	36		
	-all livestock activities				Rape	(SF) 32				
					Grain Corn	(SF) 2				
					Forage	(SF) 18				
15	same as above	$8,000	$ 8,000	$12,162	Wheat	(F) 101	Alfalfa	36	Feeder Calves	43
					Rye	(S) 88	Sunflower	84		
					Rape	(SF)111	Potato	12		
					Rape	(FF) 39	Peas	36		
					Sunflower	(SF) 8				
					Forage	(SF) 16				

Table 5.1

Effect of a Change in the Level of Available Capital on Disposable Income

Plan	Activities in Plan	Bor. Limit on Crop Oper.Cap.	Amount Borrowed	Disposable Income	M.V.P.	Optimal Farm Organization: Dryland Activities (Acres)	Optimal Farm Organization: Irrigation Activities (Acres)	Optimal Farm Organization: Livestock Activities (No.)
6	-dry and irrigated cereal	$4,000	$4,000	$4,621	Capital - $.25 Bor. limit on oper. cap.- $.19 Wheat quota supply - $.44	Wheat (S) 56 Wheat (F) 22 Oat (S) 13 Barley(FF) 118 Rye (S) 88	Flax 118 Wheat 15	
7	Same as above	$6,000	$4,480	$4,714	Capital - $.06 Bor. limit on oper. cap.- $.00 Wheat quota supply - $.44	Wheat (S) 34 Wheat (F) 22 Barley(FF) 118 Rye (S) 88	Wheat 50 Flax 118	

of capital fell to $.06. The effect of an increase in capital would have been more pronounced had there not been a marketing restriction. For both plans considered, an increase in the wheat quota supply by 1 bushel would have increased the value of the plan by $.44.

When comparing both plans we conclude that an additional dollar to be used for operating expenses contributes $.19 more to Plan 6 than to Plan 7. Thus for any given plan, increasing the availability of capital not only increases the disposable income but also reduces its M.V.P. It should also be noted that in Plan 7 only $4,480 of the $6,000 limit was borrowed. Capital was borrowed up to that level at which the M.V.P. of capital (0.06) was less than or equal to the price of borrowed capital ($0.08).

Effect of changes in available land. The original matrix allowed the farm operator the flexibility of acquiring additional acreages of land to a limit of 160 acres. To examine the effect of changes in the amount of land available for production consider Plans 9 and 13 (Table 5.2). These plans are alike except in Plan 9 it was possible to rent stubble land up to a maximum of 160 acres, whereas in Plan 13 no land was available for rent. When comparing the disposable incomes for each plan it is concluded thatavail-ability of land increases the disposable income from $11,905 in Plan 13 to $11,962 in Plan 9 where the optimal solution included the rental of 18 acres of stubble land as shown in Table 5.8. In Plan 13 where the restriction on land supply was greater, the M.V.P. of land was $7.11. This decreased to an M.V.P. of $4.56 in Plan 9.

Effect of changes in available labor. Plans 9 and 14 can be compared to examine the effect of changes in the quantities of seasonal labor

Table 5.2

Effect of Changes in the Availability of Land and Labor on Disposable Income

Plan	Activities in Plan	Additional Restriction	Disposable Income	M.V.P.		Optimal Farm Organization					
						Dryland Activities Acti (Acres)			Irrigation Ac. (Acres)		Livestock (No.)
9	-all dry and irrigated cropping activities	-	$11,962	Stubble land	$4.56	Wheat	(F)	22	Sunflower	84	Feeder Calves 50
						Rye	(S)	88	Potatoes	12	
	-all livestock activities			October labor	$ .99	Rape	(SF)	32	Field Peas	36	Feeder Hogs 20
						"	(FF)	118	Alfalfa	36	
						Grain Corn	(SF)	2			
						Forage	(SF)	18			
13	Same as above	No land available	$11,905	Stubble land	$7.11	Rye	(S)	88	Alfalfa	36	Feeder Calf 50
						Grain Corn	(SF)	6	Sunflower	84	Feeder Hogs 20
						Rape	(SF)	10	Potato	12	
						Rape	(FF)	140	Field Peas	36	
						Forage	(SF)	18			
14	Same as above	Only summer labor avail. for hire	$11,806	October labor	$2.43	Wheat	(F)	32	Flax	50	Feeder Calf 50
						Rye	(S)	88	Alfalfa	36	Feeder Hogs 20
						Grain Corn	(SF)	2	Sunflower	33	
						Rape	(SF)	42	Potato	12	
						Rape	(FF)	108	Field Peas	36	
						Forage	(SF)	18			

which can be hired. This is an important consideration since much of the hired farm labor demanded is seasonal and variable and consequently the supply of hired labor is itself variable. The effect of such changes of labor supply on production are indicated from these plans since they only differ in the level of seasonal labor available for hire. Plan 9 allows the farm operator to hire seasonal labor whereas Plan 14 allows only summer labor to be hired. One of the effects as shown in Table 5.2 is that disposable income has been reduced from $11,962 for Plan 9 to $11,806 for Plan 14. The increased restriction in Plan 14 caused the M.V.P. of October labor to rise from $.99 in Plan 9 to $2.43 in Plan 14. October labor was the only type of labor which was exhausted.

Effect of marketing quotas. Whenever production is diversified marketing quota restrictions have little or no effect on farm organization. The most profitable activities are brought into the final solution and the results indicate that in such plans the quantities of grains produced can easily be sold without exhausting the quota supply (total assignable acreage). The plans in which marketing quotas were not a limiting factor are 3, 8, 9, 10, 11, 13, 14, 15.

In Plans 1, 6 and 7 where cereal crops were the only production activities considered, the value to the plans of a one bushel increase in the wheat quota supply were $.46, $.44 and $.44. This is given in Table 5.3. When rapeseed and sunflower were added as alternative enterprises the degree of restriction imposed by the quotas decreased. Thus the M.V.P. of wheat quota supply fell to $.007 in Plan 2. In Plans 4 and 12 where livestock activities were added to the cereal crops some of these grains were used as

Table 5.3

Effect of Marketing Quotas on Production for Various Plans

Plan	Activities in Plan	Bor. Limit on Oper.Cap.	MVP of Wheat Quota Supply Restraint	Disposable Income	Land Rented (Acres)
1.	Dryland Cereal	Crops - $6,000	$.46	$4,389	0
2.	Dryland Cereal, Rapeseed Sunflower	Crops - $6,000	$.007	$8,254	105
3.	Dryland Cereal, Rapeseed, Sunflower, Special Crops	Crops - $6,000	$.00	$9,273	79
6.	Dryland and Irrigated Cereal	Crops - $4,000	$.44	$4,621	0
7.	Same as above	Crops - $6,000	$.44	$4,714	0

feed and thus the values to the program of a bushel increase in wheat quota supply fell from $.46 (Plan 1) and $.44 (Plan 7) to $.33 and $.42 for Plans 4 and 12 respectively.

The effect of the marketing quotas on production in the plans mentioned above is partially reflected in the acreage of land rented. For most plans where the quotas restrained production no land was rented even though the amounts of operating capital allowed to be borrowed was not exhausted.

It can thus be concluded that when crop production is restricted to cereal grains, marketing quotas are rather restrictive on production but when farm operators diversify the effect of such restraints is nullified.

Effect of changes in activities on farm income. Plan 1 which contains the crops presently cultivated on the farm generates an income of $4,389. As mentioned previously, the marketing quota restrains production and thus depresses farm income. However, the addition of rapeseed and sunflower activities to Plan 1 causes a sharp rise in disposable income to $8,254 (Plan 2).

A similar increase in disposable income is noticed when comparing similar plans under a combination of both dry and irrigated conditions. In Plan 7 where only cereal crops are considered (under dry and irrigated conditions) the disposable income is $4,714. This rises to $9,411 in Plan 8 where sunflower and rapeseed are introduced.

All of the four plans mentioned above are identical with respect to resource restrictions. The results are given in Table 5.4 and disposable incomes compared in Figure 5.0. Plans 1 and 7 are comprised of the same crops and Plans 2 and 8 are also alike. The profitability of introducing irrigation

Table 5.4

Optimal Farm Organization - Plans 1, 2, 7, and 8

Plans - Activities	Cash Oper. Capital ($)	Crop Oper. Capital Bor. ($)	Livestock Oper. Capital Bor. ($)	Optimal Farm Organization: Dryland* Activities (Acres)	Irrigated Activities (Acres)	Livestock Activities (No.)	Disposable Income ($)	Limiting Resources	MVP of Limiting Resources ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. -Dryland Cereal	4,000	2,430		Wheat -S 106 Barley -FF 118 Flax -S 96 -FF 22 Rye -S 88			4,389	Stubble Land Fallow Land Capital WHTQ**	5.61 11.13 .06 .46
2. -Dryland Cereal -Dryland Rapeseed -Dryland Sunflower	4,000	6,000		Wheat -SF 7 Wheat -F 111 Rapeseed -SF 150 Sunflower -SF 150 Rye -S 88 Barley -FF 28			8,254	October Labor Stubble Land Fallow Land Capital Bor. Lv. Cap. WHTQ	1.45 6.65 13.69 .16 .10 .007
7. -Dry & Irrig. Cereal	4,000	4,480		Wheat -S 34 Wheat -F 22 Barley -FF 118 Rye -S 88	Wheat 50 Flax 118		4,714	Stubble Land Fallow Land Capital Irrig. Land WHTQ	5.36 10.35 .06 7.94 .44
8. -Dry & Irrig. Cereal, Sunflower, Rapeseed	4,000	6,000		Wheat -F 77 Rye -S 88 Rapeseed -SF 87 Rapeseed -FF 63	Flax 18 Sunflower 150		9,411	October Labor Stubble Land Fallow Land Irrig. Land Capital Bor. Crop Cap.	1.42 6.49 10.70 14.34 .23 .18

*Code: S = stubble, unfertilized; SF = stubble, fertilized; F = fallow, unfertilized; and FF = fallow, fertilized.

**Code: WHTQ = wheat quota supply restraint.

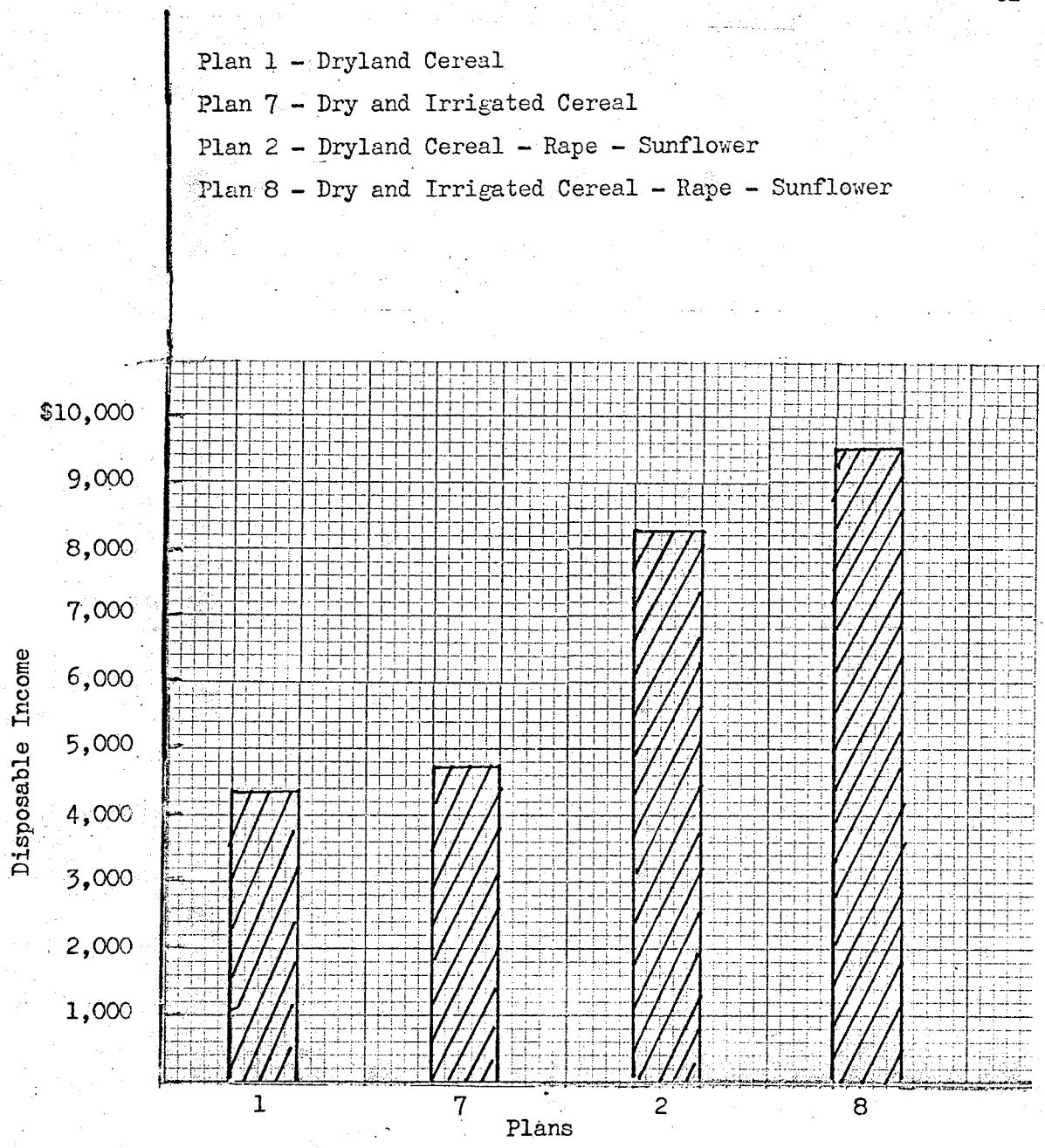

Figure 5.0

Comparison of Incomes from Cereals and a Cereal - Rapeseed - Sunflower Combination - Dry and Irrigated

to the farm is reflected in the increase in disposable income. When considering the crops presently grown on the farm (Plan 1) it is shown that disposable income increases from $4,389 for dryland production to $4,718 (Plan 7) for dry and irrigated conditions. For the plans which include rapeseed and sunflower, the introduction of irrigation increases disposable income by $1,157.

From a comparison of the four plans discussed above the direction of change indicated to the farm operator is to diversify the present dryland production by including rapeseed and sunflower. This approximately doubles disposable income. A further change is suggested by Plan 8 where the introduction of irrigation causes income to rise further by $1,157.

If forage grass, alfalfa, corn and livestock activities were included with the present dryland crops as shown in Plan 4 there will be an increase in farm income. However this increase arising from the introduction of livestock is only $763 as compared to $3,865 when sunflower and rapeseed were introduced. It should be indicated here that no market is assumed for forage, alfalfa or corn (Table 5.5).

Under dry and irrigated conditions addition of livestock and others to cereal crops raises income from $4,714 (Plan 7) to $5,790 (Plan 12). As evidenced under dryland production this increase is much less than that experienced when rapeseed and sunflower were introduced. The higher income when comparing Plans 4 and 12 indicates the profitability of irrigation as opposed to dryland farming (Figure 5.1).

Although the introduction of livestock is not as financially rewarding as rapeseed and sunflower, nonetheless the farm operator may desire to

Optimal Farm Organization – Plans 1, 4, 7, 12, and 3

Plans – Activities	Cash Oper. Capital ($)	Crop Oper. Capital Bor. ($)	Livestock Oper. Capital Bor. ($)	Optimal Farm Organization: Dryland* Activities (Acres)	Optimal Farm Organization: Irrigated Activities (Acres)	Optimal Farm Organization: Livestock Activities (No.)	Disposable Income ($)	Limiting Resources	MVP of Limiting Resources ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. –Dryland Cereal	4,000	2,430		Wheat –S 106 Barley –FF 118 Flax –S 96 Flax –FF 22 Rye –S 88			4,389	Stubble Land Fallow Land Capital WHTQ**	5.61 11.13 .06 .46
4. –Dryland Cereal –Dryland Forage, Corn, Alfalfa [No Markets For Forage Grass, Corn, Alfalfa] –All Livestock Act.	4,000	2,801	8,000	Flax –S 118 Wheat –S 51 Wheat –F 22 Oat –S 10 Barley –FF 118 Rye –S 88 Alfalfa –S 20 Forage –SF 17		Feeder Calves 43	5,154	Stubble Land Fallow Land Capital Bor. Lv. Cap. WHTQ	6.43 12.18 .06 .14 .33
7. –Dry & Irrig. Cereal	4,000	4,480		Wheat –S 34 Wheat –F 22 Barley –FF 118 Rye –S 88	Wheat 50 Flax 118		4,714	Stubble Land Fallow Land Capital Irrig. Land WHTQ	5.36 10.35 .06 7.94 .44
12. –Dry & Irrig. Cereal –Dry & Irrig. Forage, Corn, Alfalfa [No Markets For Forage Grass, Corn, Alfalfa] –All Livestock Act.	4,000	4,652	10,000	Wheat –F 22 Oat –S 18 Barley –FF 118 Rye –S 88 Forage –S 16	Wheat 33 Flax 118 Alfalfa 10 Grain Corn 6	Feeder Calves 50 Feeder Hogs 23	5,790	Stubble Land Irrig. Land Fallow Land Capital Bor. Lv. Cap. WHTQ	5.44 7.71 10.05 .06 .42 .11
3. –Dryland Cereal –Dryland Rapeseed –Dryland Sunflower –Dryland Spec. Crops –Dryland Alfalfa, Corn	4,000	6,000		Wheat –F 68 Rye –S 88 Rapeseed –SF 150 Sunflower –SF 118 Potato –SF 12 Field Peas –FF 36 Alfalfa –FF 36			9,273	October Labor Stubble Land Fallow Land Capital Bor. Crop Cap.	1.40 6.40 10.85 .22 .17

*Code: S = stubble, unfertilized; SF = stubble, fertilized; F = fallow, unfertilized; and FF = fallow, fertilized.

**Code: WHTQ = wheat quota supply restraint.

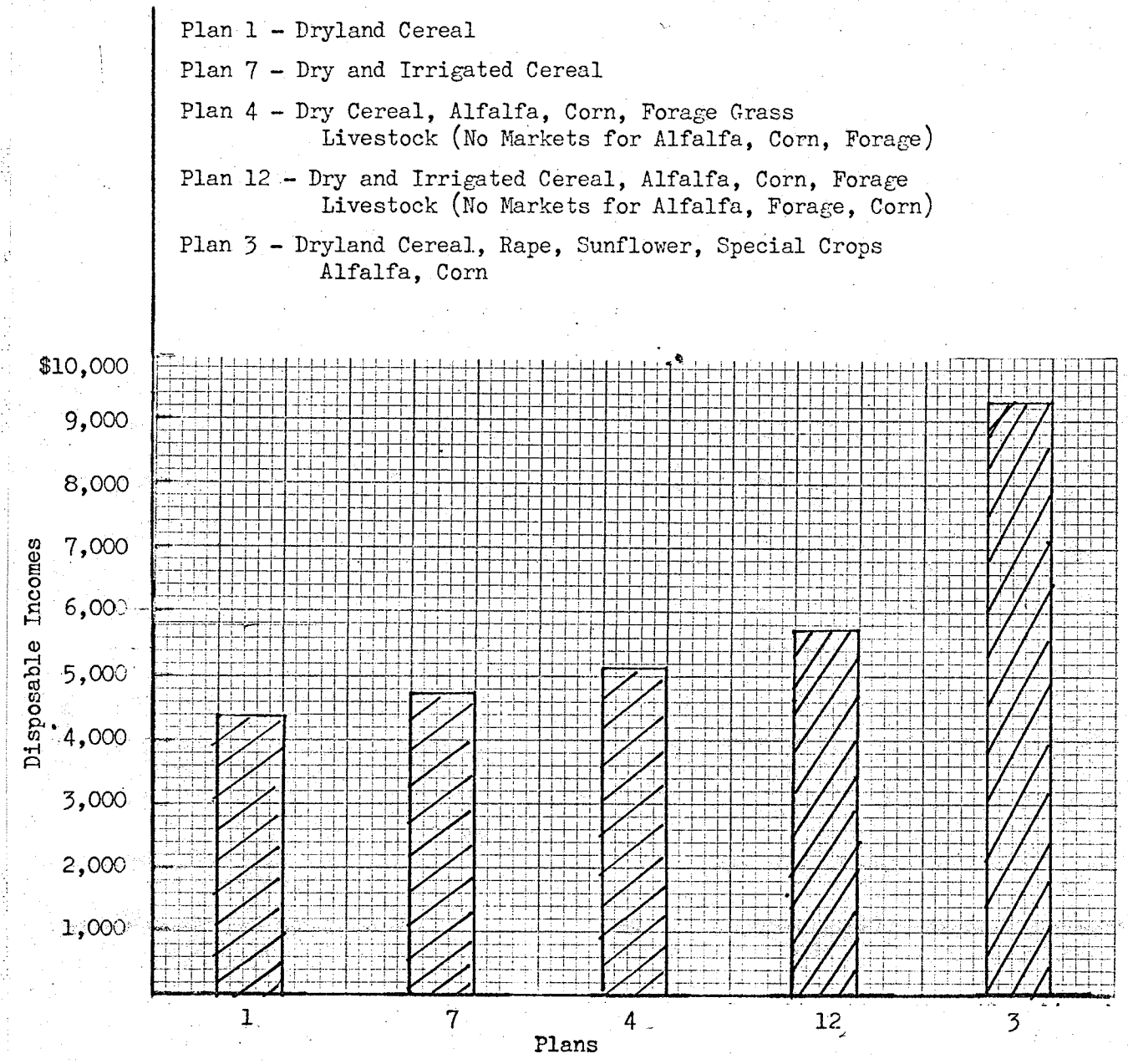

Figure 5.1

Effect of Diversification on Income - Dry and Irrigated

include these so as to increase diversification. In Plan 3 crops such as potatoes, peas, alfalfa and grain corn are added to those in Plan 2. The introduction of these special crops increases disposable income to $9,273. The results of the above mentioned plans are given in Table 5.5.

Plan 5 includes all dryland cropping activities and all livestock activities which were mentioned in Chapter IV. This plan offers much more diversification and thus quota restraints are no longer limiting factors on production. Disposable income has risen from $4,389 for the present dryland plan (Plan 1) to $9,394.

Comparing similar plans under irrigation, disposable income rose from $4,714 (Plan 7) to $11,962 (Plan 9). The results for Plans 1, 5, 7, 9 are given in Table 5.6. The incomes are compared on the graph in Figure 5.2.

Plan 9 is one of the most profitable plans considered. It also allows the greatest diversification and consist of production under dry and irrigated conditions. For the farm considered where present production includes only those activities shown in Plan 1, the farm operator should seek a direction of change which will maximize his farm income and if possible, stabilize farm income. The results suggest the inclusion of rapeseed, sunflower, special crops, forage crops and livestock with the cereal crops of Plan 1. The cultivation of these crops under dry and irrigated conditions (Plan 9) will increase the returns further.

Under Plan 9 there are two stabilizing factors on farm income. These are irrigation, which illiminates the risk of drought, and diversification in production which reduces risk of losses from changes in market

Table 5.6

Optimal Farm Organization – Plans 1, 5, 7, and 9

Plans – Activities	Cash Oper. Capital ($)	Crop Oper. Capital Bor. ($)	Livestock Oper. Capital Bor. ($)	Optimal Farm Organization: Dryland* Activities (Acres)	Irrigated Activities (Acres)	Livestock Activities (No.)	Disposable Income ($)	Limiting Resources	MVP of Limiting Resources ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. –Dryland Cereal	4,000	2,430		Wheat –S 106 Barley –FF 118 Flax –S 96 Flax –FF 22 Rye –S 88			4,389	Stubble Land Fallow Land Capital WHTQ**	5.61 11.13 .06 .46
5. –Dryland Cereal, Rapeseed, Sunflower, Spec. Crops, Forage Crops –Livestock	4,000	6,000	8,000	Wheat –F 68 Rye –S 88 Rapeseed –SF 150 Sunflower –SF 100 Alfalfa –FF 36 Potato –SF 12 Field Peas –FF 36 Forage Grass–SF 16		Feeder Calves 43	9,394	October Labor Stubble Land Fallow Land Capital Bor. Lv. Cap. Bor. Crop Cap.	1.40 6.40 10.85 .22 .17 .10
7. –Dry & Irrig. Cereal	4,000	4,480		Wheat –S 34 Wheat –F 22 Barley –FF 118 Rye –S 88	Wheat 50 Flax 118		4,714	Stubble Land Fallow Land Capital Irrig. Land WHTQ	5.36 10.35 .06 7.94 .44
9. –All Dryland & Irrig. Act. –All Livestock Act.	4,000	6,000	10,000	Wheat –F 22 Rye –S 88 Rapeseed –SF 32 Rapeseed –FF 118 Grain Corn –SF 2 Forage –SF 18	Alfalfa 36 Sunflower 84 Potato 12 Peas 36	Feeder Calves 50 Feeder Hogs 20	11,962	October Labor Stubble Land Irrig. Land Fallow Land Capital Bor. Crop Cap. Bor. Lv. Cap.	.99 4.56 13.08 7.53 .16 .13 .01

*Code: S = stubble, unfertilized; SF = stubble, fertilized; F = fallow, unfertilized; and FF = fallow, fertilized.

**Code: WHTQ = wheat quota supply restraint.

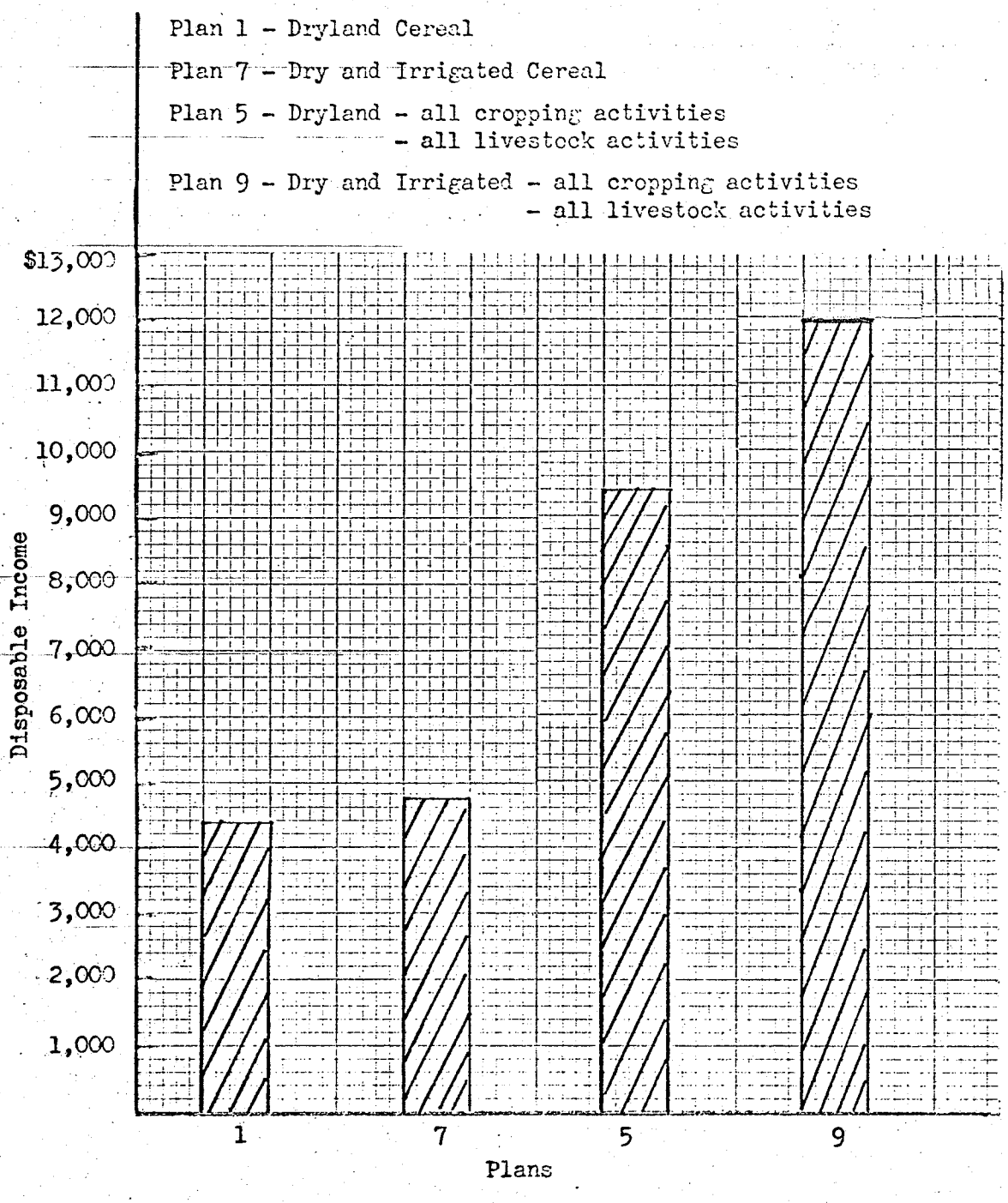

Figure 5.2

Comparing Incomes from Plans with Only Cereal and with All Activities - Dry and Irrigated

conditions, losses due to insects and disease, and losses from adverse weather conditions. The stability of farm income is a desirable element in farming. It enables the farm operator to plan ahead more confidently. He can formulate strategies for investment, expansion and growth of the farm firm. With relatively stabilized income the farm operator should find it easier to secure farm loans. Plan 9 is thus most desirable since it yields a good profit and gives the greatest stability to the farming enterprise.

Effect of different irrigation systems on disposable income. It was hypothesized in Chapter I that for the representative farm considered a tow-line irrigation system will be more profitable. Both the tow-line and self-propelled system can be used to irrigate a maximum of 168 acres. However the annual fixed cost is much greater for the self-propelled system than for the tow-line. The tow-line system requires 38.64 hours of labor annually for setting up and putting away the system (Appendix C). On the other hand because of the greater complexity of the self-propelled system 78.96 hours of fixed labor are required annually. When considering the variable labor per irrigation and the variable cost of pumping irrigation water each system exhibits certain characteristics which will make it more desirable for a particular type of farm. The tow-line system uses .29 hours of labor per irrigation as opposed to .06 hours for the self-propelled system. The variable pumping cost per acre-inch using the tow-line system is $.40 whereas for the self-propelled system it is $1.04.

Consequently, for a farm where labor is more restrictive than operating capital the self-propelled system should be more desirable, whereas the tow-line system might be preferred when capital is more restrictive. To be conclusive as to which system should add more to farm profit the

Table 5.7

Optimal Farm Organization - Plans 8, 9, 10, and 11

Plans - Activities	Cash Oper. Capital ($)	Crop Oper. Capital Bor. ($)	Livestock Oper. Capital Bor. ($)	Optimal Farm Organization: Dryland* Activities (Acres)	Optimal Farm Organization: Irrigated Activities (Acres)	Optimal Farm Organization: Livestock Activities (No.)	Disposable Income ($)	Limiting Resources	MVP of Limiting Resources ($)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
8. -Dry & Irrig. Cereal, Sunflower, rapeseed -Towline Irrig. System	4,000	6,000		Wheat -F 77 Rye -S 88 Rapeseed -SF 87 Rapeseed -FF 63	Flax 18 Sunflower 150		9,411	October Labor Stubble Land Fallow Land Irrig. Land Capital Bor. Crop Cap.	1.42 6.49 10.70 14.34 .23 .18
11. -Dry & Irrig. Cereal, Sunflower, rapeseed -Self-Propelled Irrig. System	4,000	6,000		Wheat -F 60 Rye -S 88 Rapeseed -SF 52 Rapeseed -FF 80	Sunflower 150 Rapeseed 18		7,919	October Labor Stubble Land Irrig. Land Fallow Land Capital Bor. Crop Cap.	1.64 7.51 12.06 12.39 .26 .21
9. -All Dry & Irrig. Cropping Act. -All Livestock Act. -Towline Irrig. System	4,000	6,000	10,000	Wheat -F 22 Rye -S 88 Rapeseed -FF 118 Rapeseed -SF 32 Grain Corn -SF 2 Forage -SF 18	Sunflower 84 Potato 12 Field Peas 36 Alfalfa 36	Feeder Calves 50 Feeder Hogs 20	11,962	October Labor Stubble Land Irrig. Land Fallow Land Capital Bor. Crop Cap. Bor. Lv. Cap.	.99 4.56 13.08 7.53 .16 .13 .01
10. -All Dry & Irrig. Cropping Act. -All Livestock Act. -Self-Propelled Irrig. System	4,000	6,000	10,000	Rye -S 82 Rapeseed -FF 140 Alfalfa -S 36 Forage -SF 18	Rapeseed 10 Sunflower 94 Potato 12 Field Peas 36 Grain Corn 1	Feeder Calves 50 Feeder Hogs 20	10,627	October Labor Stubble Land Fallow Land Capital Bor. Crop Cap. Bor. Lv. Cap.	1.81 1.90 6.10 .52 .48 .004

*Code: S = stubble, unfertilized; SF = stubble, fertilized; F = fallow, unfertilized; and FF = fallow, fertilized.

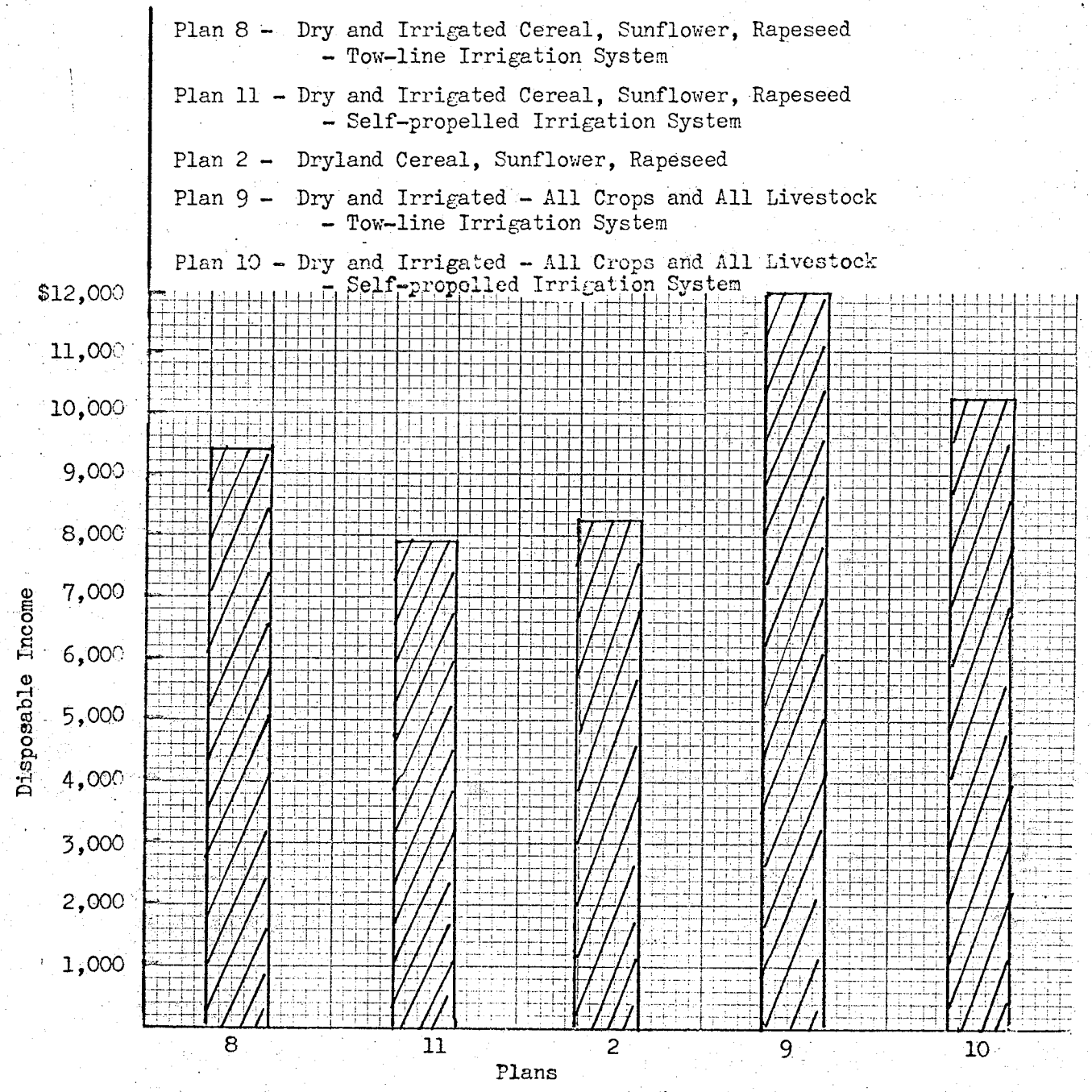

Figure 5.3

Effect of the Two Types of Irrigation Systems on Disposable Income

Table 5.8

Resources Acquired in the Various Plans

Resources Acquired \ Plan		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Molasses	cwt.				86					100	100		100	100	100	86
Urea	cwt.				17					20	20		20	20	20	17
Oats	bu.									175	175			175	175	
Barley	bu.															
Land	ac.	0	105	79	14	76	0	0	53	18	0	18	0	NA*	29	101
October Labor	hrs.	0	16	81	0	62	0	0	57	116	69	33	0	105	NA*	178
Irrigation Water	ac.-in.	-	-	-	-	-	1,331	1,585	1,735	1,975	1,529	1,681	1,700	1,975	1,975	1,975
Ratio: Disposable $/ dollars invested		.68	.83	.93	.35	.52	.58	.56	.94	.60	.53	.79	.31	.59	.59	.61

*Not available.

annual fixed cost must also be considered. This is done in Plans 8 and 11 and Plans 9 and 10. The results are given in Table 5.7 and incomes in Figure 5.3. In Plans 8 and 11 dry and irrigated sunflower, rapeseed and cereal crops are considered. The use of the tow-line system in Plan 8 proves to be more profitable returning a disposable income of $9,411. The self-propelled system in Plan 11 generated an income of $7,919. It should be noted that the very same activities can produce a higher disposable income ($8,254) under dryland production in Plan 2 than when irrigating with a self-propelled system. However when comparing these, it must be remembered that dryland production values are subject to greater uncertainty than irrigated production.

In Plans 9 and 10 where all cropping and livestock activities are considered again the use of the self-propelled system yields a lower income. Thus with the given resources for the representative farm production is more profitable when a tow-line irrigation system is used.

Demand for irrigation water. The value of irrigation to the farm was estimated in Plan 16. The activities and resources considered are those of Plan 9. This was based on the optimal level of irrigation water (Appendix C) required to attain the irrigated yields for the various crops as shown in Appendix B. When the available water supply was small (close to zero), its values (marginal value products or shadow prices) to the plan were quite high, but as greater amounts of water were made available they were used in the production of less profitable activities thus yielding M.V.P.'s of lower values. Table 5.9 gives the M.V.P.'s for various levels of irrigation water. This is plotted in Figure 5.4 to give the stepped demand function for water. It represents a derived demand. The stepped

Table 5.9

The Marginal Value Products of Irrigation Water for Various Levels of Water Use

Range of Irrigation Water Input with Constant MVP (Ac.-Ins)	Marginal Value Product of Irrig. Water ($)
0 - 27.3	$11.38
27.3 - 99.9	9.84
99.9 - 227	3.50
227 - 471	3.08
471 - 723	1.06
723 - 860	.92
860 - 1,587	.89
1,587 - 1,599	.78
1,599 - 1,709	.72
1,709 - 1,746	.55
1,746 - 1,812	.51
1,812 - 1,828	.48
1,828 - 1,975	.34
1,975	0

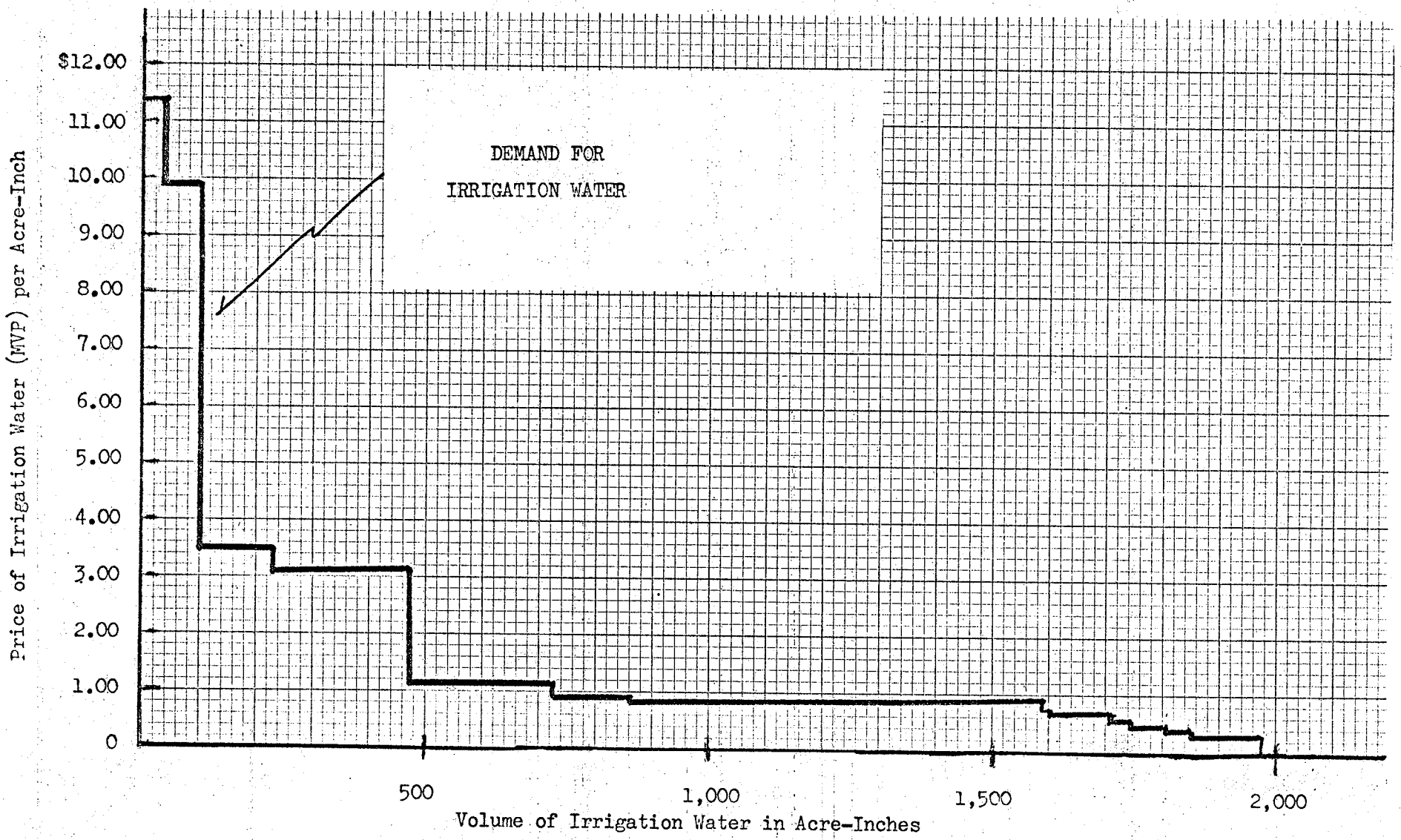

Figure 5.4

Derived Demand for Irrigation Water for the Representative Farm

function in Figure 5.4 can be approximated by the conventional negatively sloped demand function. For the first 500 acre-inches of water the function is quite steeply sloped (less than -2) but beyond this level the function becomes almost horizontal.

If irrigation water is priced, then these results indicate the amounts of water which the farm operator is willing to purchase at various prices. If the price rises above $11.38 no water will be used. As the price falls from $11.38 to $1.06 consumption increases from 0 to 471 acre-inches. For a further fall in the price of water from $1.06 per acre-inch to $.72 per acre-inch the increase in irrigation water consumed is now approximately 1,238 acre-inches. Finally at zero price per acre-inch the consumption remains at a maximum level 1,975 acre-inches.

The analysis presented in this Chapter attempts to demonstrate the effect of various factors on the farming enterprise. Though this can vary from one farm to the next it can nonetheless be extended so as to offer guidelines to other farm operators.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Fluctuations in farm income and in general the relatively low level of returns to farming in the Souris Basin have comprised one of the major farming problems in the area. This is partially due to the inadequate supply of plant moisture during the growing season. However, the presence of a good potential of underground water in the Souris Basin area together with the water of the Souris River and its tributaries have prompted this study—an investigation into the economic feasibility of introducing irrigation to the Souris Basin.

The broad objective of this study is the determination of the most efficient economic organization of the representative farm given the many constraints. More specifically this study was designed to:

(i) Find the optimal farm organization under the present dryland conditions.

(ii) Study the effect on farm profit by the introduction of rapeseed and sunflowers as production alternatives.

(iii) Determine what the optimal farm organizations should be when production is allowed to diversify among cereal crops, oilseeds, other special crops, forage crops and livestock alternatives.

(iv) Determine whether a tow-line or self-propelled sprinkler irrigation system is most appropriate.

(v) Find what the optimal farm organizations are when irrigated and dryland activities compete for the available resources.

(vi) Observe the effect on farm income when the borrowing limits on operating capital are varied.

(vii) Observe the change in disposable income when the additional resources (such as land, labor, capital) which were possible are no longer available.

(viii) Estimate the value of irrigation water to the farm—that is, its demand function for water.

In an attempt to attain the above objectives it was necessary to develop a representative farm for the Souris Basin. This was based on data obtained from the Census of Canada. The tool which was used to test the hypotheses established in this study is linear programming. The model is static and monoperiodic and sixteen analytical plans were formulated so as to facilitate the analysis.

Data were derived from several sources. The basis for much of the physical input data and the costs of production were 'Input-Output Data for Agricultural Production in Manitoba' by John Nicolson and various publications by the Manitoba Department of Agriculture. Estimates on yields were obtained from: (i) a survey in the Souris-Altona area, (ii) experimental trials at Melita, (iii) the South Saskatchewan Irrigation Project at Outlook, Saskatchewan and (iv) the Lower Yellowstone Irrigation Project in South-west North Dakota and North-east Montana.

Conclusions

In general it can be concluded that mixed farming (dry and

irrigated) is more profitable than mere dryland farming. However the actual increases in farm profits above dryland returns varies substantially with the type of irrigation system used. In this study, given the resources of the representative farm, it was found that when irrigating with a tow-line sprinkler irrigation system the increases in profits above dryland production were quite great. However the introduction of the more costly, more mechanized self-propelled irrigation system yielded returns which were very close to that obtained when the same activities were allowed under dryland production. For one of the plans the return using this system was slightly greater than it was for a similar dryland plan whereas for another the disposable income generated was lower.

The results of this study indicate the contribution of irrigation inputs to farm income. Economically it is feasible for the farm operator to introduce irrigated activities to his farming enterprise. It must however be emphasized that the choice of the appropriate irrigation system is a critical factor in determining how much of an increase in disposable income can be attributed to irrigation inputs. For the representative farm chosen in this study the rather high restrictive nature of capital and more generous supply of labor warranted a tow-line system. However in the event that the farm operator owns a greater amount of capital and more restrictive amounts of labor a more automated system such as the self-propelled system might be desirable.

Finally, the level of farm income is not the only economic consideration when assessing the value of irrigated production. The degree of stability in farm income over time is also an important consideration. On this basis either system is economically relevant to farming units.

Assuming that one of the main objectives of the farm operator is to maximize disposable income then his ability to identify those production activities which contribute most to farm profit will certainly facilitate the realization of the stated objective. In the Souris Basin of Manitoba rapeseed and sunflower seem to have rather high returns per acre. This together with the fact that marketing restrictions for these crops are quite lax have made these crops some of the most profitable production alternatives to the cereal grains. Of course, one cannot overlook the high returns per acre from other special crops such as potatoes or field peas but the rather limited markets and in some cases the high consumptive use of labor for producing these crops have made them less desirable alternatives for the farming unit as a whole than rapeseed and sunflower.

Of all the production activities considered it was established from the results that the livestock activities are the least profitable. Discussions with farm operators in the area confirm this finding. In fact it was felt that maintaining the narrow profit margin in a livestock enterprise demanded rather high managerial ability.

The recommendation of any particular production pattern to a farm operator should be made not only on the net returns per acre but on the basis of total contributions to the farming unit. In the farming sector of the economy where the degree of uncertainty is high with respect to physical conditions—weather, insects, diseases during the growing season, and with respect to the market conditions for the farm produce, it is in the best interest of the farming enterprise that production be diversified.

On the basis of the results of this study the most profitable group

of alternatives, considering the various constraints, is the sunflower-rapeseed combination. The returns to these are excellent under irrigated conditions. These were included in the selected farm plan—Plan 9. However the results did not fail to recommend other production alternatives—other special crops, forage crops and livestock to be included in the optimal farm organization of Plan 9. Though these activities are less profitable they allow the risk of the farming unit to be distributed over a larger number of activities.

Diversified production can be helpful in overcoming some marketing problems. In the Souris Basin as is typical of Prairie Agriculture cereal crops constitute most of the cultivated acreage. Since most of these marketed under quotas it was shown in this study that when production is confined to the cereal crops the number of acres put into cultivation is rather low and farm income is itself relatively low. It can be concluded here that farm income, when producing only cereal grains, is highly dependent on the levels of the marketing quotas. However the results of this study demonstrates that marketing quotas impose little or no restriction on production when production is diversified. In addition to feeding some of the grains to livestock, production of cereal grains decreases whilst at the same time the level of assignable acreage increases (more acres cultivated).

The actual values (shadow prices) of the farm resources in any particular plan depend on the activities being produced and the levels of the available resources. However, in general, capital and land were the most restrictive except in the plans where only cereal crops were offered for production. Here the marketing quotas showed higher shadow prices than capital.

From the rather steep nature of the demand function for irrigation water it can be concluded that only a small quantity of water make a high contribution to farm income. Thus if water is priced one would expect a substantial decrease in the amount of water purchased for irrigation.

Finally, from the optimal solutions of the various dryland plans it can be said that sunflower, rapeseed and some cereal crops were the main components. However when irrigation was introduced dryland acreage was mainly comprised of rapeseed and cereal crops. The largest percentage of irrigated land was put into sunflower production. Other crops irrigated were alfalfa, potato, field peas. It is interesting to note that when available labor was reduced the acreage of irrigated sunflower decreased substantially whilst at the same time flax became an important irrigated crop. When only cereal crops were considered for production flax comprised most of the irrigated acreage.

Thus to recapitulate, it can be said that the introduction of irrigation to the Souris Basin is profitable. It also reduces variability in yields. Farm operators should not only irrigate but also diversify production. The most profitable group of alternatives is the sunflower-rapeseed combination though others should be included. When irrigating, assuming adequate labor, sunflower and other special crops are chosen.

APPENDICES

APPENDIX A

PRICES OF INPUTS AND FARM PRODUCE

Table A-1

Average Prices for Farm Produce*

Products	Unit	Average Price (1967, 1968, 1969) $
Wheat	Bu.	1.48
Oats	Bu.	.58
Barley	Bu.	.86
Rye	Bu.	1.00
Flax	Bu.	2.84
Rape	Bu.	2.09
Sunflower	Lb.	.048
Peas	Bu.	1.98
Potatoes	Bu.	.98
Alfalfa	Ton	18.16
Corn (grain)	Bu.	1.41
Steers (live wt.)	Cwt.	27.61
Hogs (carcass wt.)	Cwt.	30.37

*Source: Manitoba Department of Agriculture, Yearbook of Manitoba Agriculture - 1967; 1968; 1969 (Winnipeg: Queen's Printer).

Table A-2

Prices of Major Inputs Used in Production

Inputs		Units	Prices ($)
Molasses		Cwt.	1.70
Urea		Cwt.	5.00
Commercial Starters (Hogs)		Lb.	.043
Supplement (Hogs)		Lb.	.07
Calves		Lb.	.40
Yearling		Lb.	.31
Hogs (Feeders)		Each	20.00
Land		Acre	8.00
Labor:	Spring	Hr.	1.75
	Summer	Hr.	1.50
	Fall	Hr.	1.50
	October	Hr.	1.75
Fertilizer:	Nitrogen	Lb.	.08
	Phosphorous	Lb.	.08
	Potassium	Lb.	.045
Short-term Capital		$1.00	1.08

Table A-3

Estimation of Fixed Costs for the Representative Farm

Items	Amounts ($)
1. Land Taxes:	
610 acres @ $2/acre	1,220.00
2. Telephone, hydro, building depreciation	450.00
3. Building and equipment insurance	120.00
4. Canada Pension payable on self-employed earnings	169.20
Total Fixed Cost	1,959.20

Table A-4

Estimated Maximum Long Term Loan (F.C.C.) Available to the Representative Farm

Items	Amounts ($)
1. Market value of farm	
610 acres @ $80/acre	48,800
2. Productive value of farm*	39,040
3. Maximum loan available	
-75% of productive value	29,280

*The productive value of the farm was assumed to be 80 percent of the market value. This estimate was based on discussions with the manager of Farm Credit Corporation (F.C.C.), Winnipeg.

Table A-5

Estimated Income Tax Payable on Various Levels of Net Income

Net Income* (Cash Generated) $	Income Tax Payable** (Federal and Provincial) $
3,000	8.40
4,000	173.90
5,000	393.10
6,000	647.90
7,000	923.80
9,000	1,544.10
11,000	2,201.15
13,000	3,040.43
15,000	4,017.10
17,000	5,129.10
19,000	6,312.88
21,000	7,564.88
23,000	8,815.88

*Net Income = Gross Income - Expenses (including fixed costs - taxes, hydro, depreciation, etc.)

**Income tax is calculated on the basis of the taxable income which equals net income - personal exemption ($2,950). It was assumed that a farm family comprising of the farmer, his wife and two children will have a personal allowance of $2,950.

APPENDIX B

COST OF PRODUCTION ESTIMATES

Table B-1

Time Required for Maturity of Various Crops *

Crops	Time to Mature (days)
Wheat	90 - 100
Oats	84 - 86
Barley	83 - 88
Flax	91 - 97
Corn - Grain	110 - 120
Peas	90 - 100
Rape - Early	73 - 83
Rape - Late	92 - 102
Sunflowers	120 - 130

*Source: Faculty of Agriculture and Home Economics, The University of Manitoba, Principles and Practices of Commercial Farming (Winnipeg: The Public Press Limited, 1965).

Table B-2

Tillage Practices for Crops - Dryland and Irrigated

Crop	Tillage
Dryland	
Cereal - fallow	Cu - Dr - H - Sp - Sw - Co - Ha - Ow
Flax - fallow	Cu - H - Dr - H - Sp - Sw - Co - Ha - Ow
Rape - fallow	Cu - H - Dr - H - Sw - Co - Ha - Ow
Cereal grains - stubble	Cu - 3H - Dr - Sp - Sw - Co - Ha - Ds - H
Flax - stubble	Cu - 3H - Sp - Sw - Co - Ha - Cu - H
Sunflower - stubble	Cu - Ds - H - Dr - Cr - Co - Ha - Cu - H
Rape - stubble	Cu - 3H - Dr - Sw - Co - Ha - Cu - H
Field Peas	Cu - Dr - H - Sp - C - Ha - Cu - H
Potatoes	P - Ds - Pl - H - Sp - 2Cr - Hv - Ha - Cu - H
Silage Corn	Cu - H - Dr - 2Cr - Hv - Ha - Cu - H
Forage	F - M - R - B - Ha
Summerfallow	Ow - Pl - 4Cu
Irrigated (stubble)	
Potatoes	Dt - 2H - Pl - Cr - Sp - Hv - Ha - Cu - H
Corn Silage	Dt - 2H - Pl - 3Cr - Sp - Hv - Ha - Cu - H
Field Peas	Dt - 2H - Dr - Sp - Co - Ha - Cu - H
Alfalfa	F - M - R - B - Ha
Small grains	Dt - 2H - Dr - Sp - Sw - Co - Ha - Ds - H

Key for Codes in Table B

B - Bale	Ha - Haul
Co - Combine	Hv - Harvest
Cr - Row Cultivate	M - Mow
Cu - Cultivate	Ow - One-way Plow
Dr - Drill	P - Plant
Ds - Disc	Pl - Plow
Dt - Tandem Disc	R - Rake
F - Fertilize	Sp - Spray
H - Harrow	Sw - Swath

Table B-3

Machinery Cost and Man Hours Required to Work One Acre with Various Equipments - Dryland and Irrigated*

Equipment	Cost/Hr.	Mach. Hr./Ac. Dryland	Mach. Cost/Ac. Dryland	Man.Hrs./Ac. Dryland	Mach.Hrs./Ac. Irrig.	Mach. Cost/Ac. Irrig.	Man Hrs./Ac. Irrig.
Tractor	$ 1.36						
Oneway	1.00	.38	$ .89	.38	.38	$ .90	.38
Cultivator	.70	.28	.58	.28	.40	.82	.40
Harrow	.42	.12	.21	.12	.12	.21	.12
Drill and Seed	1.53	.24	.70	.48	.26	.75	.72
Disker	1.49	.24	.69	.24	.27	.77	.27
Sprayer	.70	.12	.24	.12	.12	.24	.12
Combine	10.62	.35	3.72	.70	.44	.47	.88
Swathing	1.61	.14	.42	.14	.18	.53	.18
Seeding - Corn	1.53	.29	.83	.58	.31	.89	.62
Row Crop Cult.	.70	.24	.50	.24	.30	.62	.30
Plow	1.00	.66	1.56	.66	.48	1.13	.48
Haul - Grain	.43	.44	.19	.50	.49	.21	.55
Mower	.16	.44	.67	.44	.44	.67	.44
Rake	.17	.38	.58	.38	.38	.58	.38
Baler	.22	.40	.63	.40	.50	.77	.50
Forage Harvester	.35	.70	1.20	.70	1.25	2.14	1.25
Harvest Grain - Corn	.40	1.20	2.03	2.40	1.35	2.35	2.70
Fertilize (Spray) - Corn	.70	.20	.14	.40	.20	.41	.40
Haul Bale	.43	.90	.39	1.80	1.00	.43	2.00
Repairs				.43			.50
Potato Harvester	.35	2.00	3.42	3.80	2.00	3.42	3.80
Tandem Disc.	20				.41	.70	.51

*Source: Department of Agricultural Economics, University of Manitoba, "Input-output Data for Agricultural Production in Manitoba", [by John Nicolson] (Unpublished - 1969).

Table B-4

Level of Application and Fertilizer Costs per Acre - Dryland*

Crops		N	P_2O_5	K_2O	Price/acre
Cereal Crops	fallow	0-20	20-30	15-30	4.47
	stubble	40-60	20-30	15-30	6.67
Rape & Mustard	fallow	0-35	20	0	4.00
	stubble	50-80	20	0	6.80
Flax	fallow	0	0	0	0
	stubble	40-60	0	0	4.00
Peas		0	10-15	0	1.30
Forage Crops		0	35-50	0	3.20
Sunflowers		40-60	20-30	0	3.25
Potatoes	stubble	60-80	30-50	30-60	10.82
	fallow	30	30-50	30-60	7.62
Corn		40-60	20-30	25-35	7.35

*Source: Manitoba Department of Agriculture, 1971 Field Crop Recommendations for Manitoba. (Winnipeg, Manitoba).

Table B-5

Level of Fertilizer Use and Fertilizer Cost per Irrigated Acre

Crops	N	P_2O_5	K_2O	$ Cost per Irrigated Acre
Cereal	65-85	20-30	15-30	8.77
Rape and Mustard	80-110	20	0	9.44
Flax	65-85	0	0	6.00
Peas	0	10-15	0	1.30
Forage Crops	0	35-50	0	3.20
Sunflowers	65-85	20-30	0	6.29
Potatoes	95-115	30-50	30-60	9.00
Corn	65-85	20-30	25-35	9.35

Table B-6

Estimated Seed Costs per Acre

Crops	Amount per Acre		Seed Cost per Acre ($)
Wheat	1 1/4 - 1 3/4	Bu.	3.82
Oats	2 - 3	Bu.	1.75
Barley	1½ - 2	Bu.	2.00
Rye	1 - 1¼	Bu.	2.03
Flax	28 - 40	Lbs.	1.96
Field Peas	2	Bu.	3.50
Rapeseed	6 - 8	Lbs.	1.28
Corn	18 - 25	Lbs.	4.25
Alfalfa	6 - 8	Lbs.	5.32
Sunflowers	5 - 10	Lbs.	1.01
Forage	6 - 9	Lbs.	2.24

Table B-7

Estimated Crop Insurance Rates per Dryland Acre

Crops	Guarantee per Acre** (Bu.)	Premium per Acre* ($)
Wheat	12	.99
Oats	22	1.15
Barley	15.75	1.42
Flax	5.37	1.24
Fall Rye	11.50	.89
Rapeseed	7.75	1.43

*Estimates were made from the Manitoba Crop Insurance Corporation -'1969 Rates and Coverages'. The Souris Basin roughly corresponds to risk areas No. 1 and 2. The guarantee per acre is based on a 60 percent coverage election and is the average for both risk areas.

**This is the average premium for risk areas No. 1 and 2 at 60 percent coverage.

Table B-8

Cost of Production Summary - Dryland

		Machine Cost	Fertilizer Cost	Seed	Insect Sprays	Crop Insurance	Total
Wheat	Fallow	$ 6.95	$ 4.47	$ 3.82	.35	.99	$16.58
	Stubble	7.38	6.77	3.82	.35	.99	19.31
Oats	Fallow	6.95	4.47	1.75	.60	1.15	14.92
	Stubble	7.01	6.77	1.75	.60	1.15	17.28
Barley	Fallow	6.95	4.47	2.00	.35	1.42	15.19
	Stubble	7.01	6.77	2.00	.35	1.42	17.55
Flax	Fallow	7.16	-	1.96	.60	1.24	10.96
	Stubble	7.27	4.00	1.96	.60	1.24	15.07
Sun-flower	Fallow						
	Stubble	9.18	4.29	1.01	1.66	-	16.14
Rape	Fallow	6.78	4.00	1.28	1.42	1.97	15.45
	Stubble	7.03	6.80	1.28	1.42	1.97	18.50
Peas	Fallow	6.56	1.30	3.50	-	-	11.36
Potatoes	Stubble	29.61	6.20	30.28	3.65	-	69.74
Sugar Beets		31.36	9.11	3.63	3.55	.89	48.54
Corn Silage		6.04	7.35	4.25	2.00	-	19.64
Alfalfa		4.82	3.20	5.32	-	-	13.34
Forage		2.41	3.20	2.24	-	-	7.85
Summerfallow		4.77	-	-	-	-	4.77

Table B-9

Cost of Production Summary per Acre - Irrigation

	Machinery Cost	Fertilizer	Seed Rep.	Spray and Chemical	Total
Wheat	$ 8.50	$ 8.77	$ 3.82	.46	$21.55
Oats	8.50	8.77	1.75	.80	19.82
Barley	8.50	8.77	2.00	.46	19.73
Flax	8.50	6.00	1.96	.80	17.26
Rapeseed	8.50	9.44	1.28	1.89	21.11
Sunflower	8.40	6.29	1.01	2.20	17.90
Sugar Beets	41.36	12.15	3.63	3.55	60.69
Potatoes	39.61	9.00	30.28	3.65	82.54
Field Peas	8.02	1.30	3.50	-	12.82
Corn Grain	12.23	9.35	4.25	2.66	28.49
Corn Silage	11.12	9.35	4.25	2.66	27.38
Alfalfa	4.86	3.20	5.32	-	13.38
Forage Grass	2.43	3.20	2.24	-	7.87

Table B-10

Estimated Labor Requirements for Dryland Crops - Hours/Acre

Activities (in hrs.)	Spring Labor	Summer* Labor	Fall Labor	Oct.** Labor	Operator*** labor	Total
Wheat - Fallow	.88	.27	1.34	.66	.32	3.47
Flax - Fallow	1.0	.27	1.34	.66	.33	3.60
Oats, Barley, Rye - Stubble	1.10	.27	1.34	.66	.34	3.71
Summerfallow		2.31			.23	2.54
Flax - Stubble	1.12	.27	1.34	.68	.34	3.75
Sunflowers	1.12	.40		1.88	.34	3.74
Rape - Fallow	1.12	-	1.34	.68	.31	3.45
Rape - Stubble	1.00	-	1.34	.66	.30	3.30
Peas - Fallow	.88	.27	1.20	.68	.30	3.33
Potatoes	4.0	3.5	14.5	12.0	3.4	37.4
Corn Silage	.88	.67	2.50	.68	.47	5.20
Forage-Stubble - Grass	.12	-	.34	1.00	.15	1.61
Forage-Stubble - Alfalfa	.12	1.22	.12	1.22	.27	2.95
Corn Grain	.88	.67	2.90	.68	.51	5.64
Alfalfa - Stubble	1.12	.27	1.34	.64	.34	3.71
Alfalfa - Fallow	.52	1.22	1.12	.22	.31	3.39

*This includes an allowance for repairs and maintenance of .15 hrs./acre.

**This includes an allowance for repairs and maintenance of .28 hrs./acre.

***Operator's supervisory labor requirements were estimated as being 10% of production labor requirement.

Table B-11

Estimated Labor Requirements for Irrigated Crops - Hrs./Acre

Crops	Spring Labor	Summer Labor	Fall Labor	Oct. Labor	Sub. Total	Operator Labor	Total Labor
Small Grains	1.47	.62	1.61	.64	4.34	.43	4.77
Sunflowers	1.47	.80	-	2.45	4.72	.47	5.19
Field Peas	1.47	.62	1.43	1.02	4.54	.45	4.99
Corn Silage	1.23	1.52	3.33	1.02	7.10	.71	7.81
Corn Grain	1.23	1.27	4.70	1.02	8.22	.82	9.04
Alfalfa	.12	3.57	2.00	1.57	7.26	.73	7.99
Forage	.12	-	1.57	2.00	3.69	.37	4.06
Potatoes	3.91	3.82	14.40	12.00	34.13	3.41	37.54
Sugar Beets	6.84	21.06	3.44	5.72	37.06	3.71	40.77

Note: Allowances made for repairs, maintenance and operator's labor are the same as for dryland labor requirements.

Table B-12

Estimated Yields of Crops - Dryland and Irrigated per Acre

Crops	Units	Dry Stubble Unfertilized	Dry Stubble Fertilized	Dry Fallow Unfertilized	Dry Fallow Fertilized	Irrigated Stubble
Wheat	Bu.	18	23.90	25.00	28.56	37.80
Oats	Bu.	39.00	44.26		55.76	75.00
Barley	Bu.	24	33.5		47.3	50
Flax	Bu.	8.2	9.22		11.00	20
Rye	Bu.	27.77	36.81			
Rape	Bu.		26.04		27.5	35.40
Sunflower	Lbs.		788.5			14.80
Field Peas	Bu.				22	55
Potatoes	Tons		6.90			12
Corn Grain	Bu.		28.96			51.88
Corn Silage	Tons		6.6			15.32
Alfalfa	Tons	1.7	2.0		2.4	4.40
Forage	Tons		2.0			4.00

Note: The yields given were obtained from the following sources:

1. Survey - a survey in the Souris and Altona Areas of Manitoba for 1968 production estimates. The survey constituted a part of this present study.

2. Saskatchewan Provincial Government, "Experimental Results of Irrigated Crop Production in the South Saskatchewan Irrigation Project", (Outlook, Sask., Unpublished data).

3. North Dakota Agricultural Experimental Station, Integrating Irrigation with Dryland Farming, Bul. No. 433 [by L.W. Schaffner and others], (Fargo, N.D., May, 1961) Appendix Tables 1 and 2.

APPENDIX C

INPUT DATA FOR IRRIGATION

Table C-1

Esimated Cost for Well Construction*

Items	Costs ($)
1. Materials**	
(a) 10" Screens (telescoping and pipe size)	1,796.20
(b) Other Fittings	624.35
(c) Provincial Sales Tax	121.00
2. Construction	
35 ft. @ $20/ft.	700.00
3. Development	
13 1/3 hrs. @ $30/hr.	400.00
Total Cost	3,641.55

*Estimates were obtained from Baker Manufacturing Limited in Winnipeg. The well is 35 feet in depth, 10 inches in diameter and designed to pump 1 cubic foot of water per second. Estimated life-time of the well is 25 years.

**The length of materials required was ten feet. Prices include a Federal Sales Tax.

Table C-2

Average Investment per Irrigation System*

System	Acres Irrigated per Farm	Cost of Well ($)	Sprinkler System ($)	Motor and Pump ($)	Pipe etc. ($)	Total Cost per System ($)
Tow-line	168	3,641.55	4,896	3,842	3,145	15,497.55
Self-Propelled	317	3,641.55	15,898	4,103	4,022	27,664.55

*Source: All values indicated, except the cost of the well were obtained from: North Dakota State University, Department of Agricultural Economics, Irrigation, Bul. No. 474 [W. McMartin, R.O. Bergan] (Fargo, N.D. March 1968) p. 24, Table 9.

Table C-3

Annual Fixed Cost per Irrigation System

System	Depreciation*	Interest**	Total
Tow-line	$1,034.33	$ 600.51	$1,634.84
Self-Propelled	1,678.88	1,072.00	2,750.88

*Depreciation rates were based on the following estimated useful life:

(i) Wells - 25 years

(ii) Pumps and Motors - 20 years

(iii) Sprinkler system and Pipes - 15 years (except for the sprinkler system of the tow-line which was 10 years).

**Interest on investment was 7 3/4 percent (F.C.C. rates) of 1/2 of capital investment.

Table C-4

Labor and Tractor Cost for Irrigating *

System	Fixed Labor per Acre for Prep. & Putting away Sys. (hrs.)	Fixed Labor per Prep. Sys. for Irrig.for 168 acres (hrs.)	Variable Labor per Irrigation (hrs.)	Tractor Cost per Irrigation ($)
Tow-line	.23	38.64	.29	.39
Self-propelled	.47	78.96	.06	.08

*Source: Estimated from: North Dakota State University; Bul. 474. op.cit., p. 30, Table 12.

Table C-5

Pumping Costs per Acre Inch*

System	Avg.Water Pumped per Acre Irrig.	Energy per Ac-In ($)	Lub-Repairs per Ac-In ($)	Total per Ac-In ($)
Tow-line	10.99 Ac.In.	.36	.04	$ .40
Self-propelled	10.99 Ac.In.	.89	.15	1.04

*Source: North Dakota State University, Bul. 474, op. cit., p. 28, Table 11.

Table C-6

Estimation of the Number of Times Irrigation Should Be Performed - Seasonally for the Various Crops*

Crops	Consumptive Use of Water (Ac-In)	Amount Available Re Rainfall (Ac-In)	Amount Required by Irrig. (Ac-In)	No. of Irrig. Required	at 50% Moisture in soil, Amount for each Irrig. (Ac-In)	Average Moisture Content of Soil (Ac-In)	No. of times		
							Spring Irrig.	Summer Irrig.	Fall Irrig.
Alfalfa	27	10.67	17.67	4.4	4	8	1	4	-
Grass Hay	24	9.39	14.61	9.7	1.5	3.0	2	7	1
Corn	19	10.67	8.33	3.3	2.5	5.0	1	3	-
Flax, Peas) Sunflower)	19	8.67	10.33	4.1	2.5	5.0	1	3	-
Potatoes	19	10.67	8.33	4.16	2.0	4.0	1	3	-
Small Grain) Rape)	16	8.67	7.33	2.90	2.5	5.0	1	2	-

*Source: Estimated from: Donahue, Roy L., An Introduction to Soils and Plant Growth. (Englewood Cliffs, New Jersey: Prentice Hall Inc., 1965).

APPENDIX D

LIVESTOCK PRODUCTION ESTIMATES

Table D-1

Costs and Return - Beef Cattle Enterprise (Calves)*

A.	Buying Costs per Calf	
	1. Steer cost 400 lb. @ 40¢/lb.	$160.00
	2. Buying Commission	1.00
	3. Trucking Cost	1.20
	Total	$162.20
B.	Feeding and Finishing Cost per Calf	
	1. Milling Costs (feed)	$ 7.20
	2. Minerals	2.10
	3. Vet., drugs, vitamins	3.00
	4. Death loss (2% of $225)	4.50
	5. Trucking out	2.85
	6. Selling cost	3.00
	Total	$ 22.65
C.	Net Returns per Calf	
	1. Total Revenue 950 lbs. @ $27.61/cwt.	$262.29
	2. Total Cost	184.85
	Net Return**	$ 77.44

*Source: Manitoba Department of Agriculture: Guidelines for Beef Production, Publication No. 513. (Winnipeg, Manitoba; June 1970).

**Does not include the cost of feed.

Table D-2

Costs and Returns - Beef Cattle Enterprise (Yearling)*

A. Buying Costs per Yearling	
1. Steer Cost 750 lb. @ 31¢/lb.	$232.50
2. Buying Commission	1.87
3. Trucking Cost	2.25
Total	$236.62
B. Feeding and Selling Costs per Yearling	
1. Milling Costs	$ 3.30
2. Minerals	1.33
3. Vet., drugs, vitamins	2.00
4. Death Loss (1% of $275)	2.75
5. Trucking Out	3.15
6. Selling Cost	3.00
Total	$ 15.53
C. Net Returns per Yearling	
1. Total Revenue (1,050 lbs. @ $27.61/cwt)	$289.91
2. Total Cost	252.15
Net Return**	$ 37.76

*Source: Manitoba Department of Agriculture, Guidelines for Beef Production, Pub. No. 513. (Winnipeg, Manitoba, June 1970).

**Does not include costs for feed.

Table D-3

Resource Requirements and Returns - Feeder Hog Enterprise

A.		
	Total Feed Required	580 lbs.
	Average Daily Gain	1.47 lbs.
	Feed Required per Pound Gained	3.32 lbs.
	Age at Market	160 - 165 days
B.	Cost of Finishing Feeder	
	1. Supplement and Commercial Starter	$ 9.04
	2. Vet., Medicine	.25
	3. Utilities	.25
	4. Insurance	.22
	5. Operating (Manure removal etc.)	.35
	6. Marketing	1.30
	7. Death Loss (3% of Purchase Price)	.81
	8. Other Costs	.25
	Total Cost	$ 12.47
C.	Cost of Purchasing Feeder	$ 20.00
D.	Net Returns per Feeder	
	Revenue - 1.5 cwt. marketed carcass @ $30.37/cwt.=	$ 45.55
	Total Cost	32.47
	Net Return	$ 13.08
E.	Labor Requirement per Feeder	1.4 hrs.

Sources: Section A: Faculty of Agriculture and Home Economics, University of Manitoba, Principles and Practices of Commercial Farming, 2nd ed., (Winnipeg: University of Manitoba, 1968) p. 290.

Section B, C, D: Manitoba Department of Agriculture, Swine Enterprise Budgets for Three Types of Enterprises, (Winnipeg, Man.: June 1970), p. 28.

Table D-4

Resource Requirements for Finishing Beef Cattle

Requirements	Restraint*	Units	Feeder Calf (400 lbs.)	Yearling Enterprise (750 lbs.)
1. Net Energy for Maintenance - NEM	≥	megcal.	847	659
2. Net Energy for Production - NEP	≥	"	737	645
3. Protein	≥	percent	11	10
4. Molasses	≤	"	5	5
5. Maximum Urea	≤	"	1.0	1.0
6. Maximum Roughage	≤	"	18.75	17.46
7. Weight of Feed	=	cwt.	40	24.75
8. Space	=	sq.ft.	22.4	22.4
9. Labor	=	hrs.	11.4	7.9
10. Weight at Purchase	=	lbs.	400	750
11. Finished Weight	=	lbs.	950	1,050

Sources:

Lines 1 and 2: Frontiers in Nutrition Supplement, Appendix to No. 192, Table 1, May 1967.

Lines 3 - 7: Faculty of Agriculture and Home Economics, University of Manitoba. Principles and Practices of Commercial Farming, 2nd ed. (Winnipeg: University of Manitoba, 1968) pp. 316-7.

Lines 8, 10, 11: Manitoba Department of Agriculture, Pub. No. 513 (Winnipeg, Man.: June 1970).

Line 9: L.W. Johnson, "An Economic Analysis of Beef Cattle Production and Grain Operations in West Central Manitoba" (Unpublished Master's dissertation, University of Manitoba, May 1969) p. 47, Table 13.

* ' ≥ ' means greater than or equal; ' ≤ ' means less than or equal.

Table D-5

Ration Used for Feeder Hog Enterprise*

1.	Oat	8.73 Bu.
2.	Corn	2.8 Bu.
3.	Total Supplement	113.8 Lbs.
4.	Total Commercial Starter	25 Lbs.

*Source: Faculty of Agriculture and Home Economics, University of Manitoba. Principles and Practices of Commercial Farming, 2nd ed., (Winnipeg, University of Manitoba, 1968) p. 290.

Table D-6

Nutrient Values of Various Feeds

Feed	Price per Cwt.	Bu. per Cwt.	NEM per Cwt.	NEP per Cwt.	Percent Protein
Wheat	-	1.67	95	62	14
Oats	-	3.12	80	50	11
Barley	-	2.68	84	53	12
Rye	-	1.78	80	50	12
Corn	-	1.78	95	62	8.9
Alfalfa	-		55	20	14
Oat Hay	-		54	19	8
Corn Silage	-		24	11	2.3
Molasses	$1.70		65	41	8
Urea	$5.00				

Table D-7

Annual Fixed Cost for a 50-Head Feedlot*

A. Investment		
Pens and Handling Facilities		$2,142
Building		1,890
Total Investment		$4,032
B. Annual Fixed Costs		
Depreciation - pens and fence	(10 yrs.)	$214.20
- shed	(20 yrs.)	94.50
Interest on capital @ 7 3/4 %		312.48
Total Fixed Cost		$621.18

*Source: Manitoba Department of Agriculture, Guidelines for Beef Production, Pub. No. 513 (Winnipeg, June 1970).

APPENDIX E

L.P. MATRIX

Table E-1

Codes for Activities in the L.P. Matrix

Activities	Code
Wheat, stubble, fertilized, dry	WSFD
Wheat, stubble, unfertilized, dry	WSD
Wheat, fallow, fertilized, dry	WFFD
Wheat, fallow, unfertilized, dry	WFD
Oat, stubble, fertilized, dry	OSFD
Oat, stubble, unfertilized, dry	OSD
Oat, fallow, fertilized, dry	OFFD
Barley, stubble, fertilized, dry	BSFD
Barley, stubble, unfertilized, dry	BSD
Barley, fallow, fertilized, dry	BFFD
Flax, stubble, fertilized, dry	FXSFD
Flax, stubble, unfertilized, dry	FXSD
Flax, fallow, fertilized, dry	FXFFD
Rye, stubble, fertilized, dry	RSFD
Rye, stubble, unfertilized, dry	RSD
Rapeseed, stubble, fertilized, dry	RASFD
Rapeseed, fallow, fertilized, dry	RAFFD
Sunflower, stubble, fertilized, dry	SNSFD
Alfalfa, stubble, fertilized, dry	ASFD
Alfalfa, stubble, unfertilized, dry	AS
Alfalfa, fallow, fertilized, dry	AFFD
Grain-corn, stubble, fertilized, dry	GCSFD
Potato, stubble, fertilized, dry	POSFD
Field peas, fallow, fertilized, dry	PFFD
Silage corn, stubble, fertilized, dry	SCSFD
Forage grass, stubble, fertilized, dry	FOSFD
Summer-fallow	SMFW

Table E-1 (cont'd)

Codes for Activities in the L. P. Matrix

Activities	Code
Wheat, fertilized, irrigated	WFI
Oat, fertilized, irrigated	OFI
Barley, fertilized, irrigated	BFI
Flax, fertilized, irrigated	FXFI
Rapeseed, fertilized, irrigated	RAFI
Sunflower, fertilized, irrigated	SNFI
Alfalfa, fertilized, irrigated	AFI
Grain-corn, fertilized, irrigated	CGFI
Silage-corn, fertilized, irrigated	CSFI
Potato, fertilized, irrigated	POFI
Field peas, fertilized, irrigated	PFI
Forage grass, fertilized, irrigated	FOFI
Transfer of non-irrigated land to stubble land supply	TRLD
Spring-irrigating-tow-line system	SPTI
Summer-irrigating-tow-line system	SUTI
Fall-irrigating-tow-line system	FATI
Pumping irrigation water - tow-line system	PCTI
Annual fixed cost of the tow-line system	FCTI
Spring-irrigating - self-propelled system	SPSI
Summer-irrigating - self-propelled system	SUSI
Fall-irrigating - self-propelled system	FASI
Pumping irrigation water - self-propelled system	PCSI
Fixed cost self-propelled system	FCSI
Transfer of assignable acres to wheat quota supply	WHQTR
Transfer of assignable acres to oat quota supply	OAQTR
Transfer of assignable acres to barley quota supply	BAQTR
Transfer of assignable acres to rye quota supply	RYQTR
Transfer of assignable acres to rapeseed quota supply	RAQTR
Transfer of assignable acres to flax quota supply	FLQTR

Table E-1 (cont'd)

Codes for the Activities in the L.P. Matrix

Activities	Code
Wheat conversion to NEM, NEP equivalents for calf ration	WNEMC, WNEPC
Oat conversion to NEM, NEP equivalents for calf ration	ONEMC, ONEPC
Barley conversion to NEM, NEP equivalents for calf ration	BNEMC, BNEPC
Rye conversion to NEM, NEP equivalents for calf ration	RNEMC, RNEPC
Grain-corn conversion to NEM, NEP equivalents for calf ration	CNEMC, CNEPC
Alfalfa conversion to NEM, NEP equivalents for calf ration	ANEMC, ANEPC
Forage grass conversion to NEM, NEP equivalents for calf ration	HNEMC, HNEPC
Silage corn conversion to NEM, NEP equivalents for calf ration	SNEMC, SNEPC
(Bought) Molasses conversion to NEM, NEP equivalents for calf ration	BMMC, BMPC
(Bought) Urea conversion to NEM, NEP equivalents for calf ration	BURAC
Wheat conversion to NEM, NEP equivalents for yearling ration	WNEMY, WNEPY
Oat conversion to NEM, NEP equivalents for yearling ration	ONEMY, ONEPY
Barley conversion to NEM, NEP equivalents for yearling ration	BNEMY, BNEPY
Rye conversion to NEM, NEP equivalents for yearling ration	RNEMY, RNEPY
Grain-corn conversion to NEM, NEP equivalents for yearling ration	CNEMY, CNEPY
Alfalfa conversion to NEM, NEP equivalents for yearling ration	ANEMY, ANEPY
Forage grass conversion to NEM, NEP equivalents for yearling ration	HNEMY, HNEPY
Silage corn conversion to NEM, NEP equivalents for yearling ration	SNEMY, SNEPY
(Bought) Molasses conversion to NEM, NEP equivalents for winter yearling ration	BMMY, BMPY
(Bought) Molasses conversion to NEM, NEP equivalents for summer yearling ration	BMMSY, BMPSY
(Bought) Urea conversion to NEM, NEP equivalents for summer and winter yearling ration	BURAY, BURASY
Feeder-calf activity	CAFE
Feeder-winter yearling activity	YEFEW
Feeder-summer yearling activity	YEFES
Feeder hog activity	HOGF

Table E-1 (cont'd)

Codes for Activities in the L.P. Matrix

Activities	Code
Buying calves	BCALF
Buying winter yearling	BWYEAR
Buying summer yearling	BSYEAR
Buying hogs	BHOG
Fixed cost for feedlot construction	ACFL
Buying oats	BOAT
Buying barley	BBAR
Borrowing capital for livestock operation	BLCAP
Borrowing capital for cropping operation	BSTCP
Hire spring labor	HSPLA
Hire summer labor	HSULA
Hire fall labor	HFALA
Hire October labor	HOCLA
Rent stubble land	RENLD
Selling wheat on quota	SWHTQ
Selling oat on quota	SOAT
Selling barley on quota	SBAR
Selling rye on quota	SRYE
Selling wheat as feed	SWHTF
Selling alfalfa	SALF
Selling grain-corn	SGCOR
Annual fixed overhead cost - land taxes, telephone etc.	ANFC
Taxation activities for incomes of \$3,000, \$4,000, \$5,000, ... \$23,000	T3, T4, T5, ..., T23
Transfer of cash from cash generated to objective function.	TRCASH

Table E-2

L.P. Matrix for Plan 9

Levels		Type* of Restraint	Restraints \ Obj. Function → / Activities →	WSFD	WSD	WFFD	WFD	OSFD	OSD	OFFD	BSFD	BSD	BFFD	FXSFD	FXSD	FXFFD	RSFD
3900	hrs.	L	Total Labor	3.71	3.71	3.47	3.47	3.71	3.71	3.47	3.71	3.71	3.47	3.75	3.75	3.60	3.71
1125	hrs.	L	Total Operator's Labor	.34	.34	.32	.32	.34	.34	.32	.34	.34	.32	.34	.34	.33	.34
700	hrs.	L	Spring Labor	1.12	1.12	.88	.88	1.10	1.10	.88	1.10	1.10	.88	1.12	1.12	1.00	1.10
1000	hrs.	L	Summer Labor	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27
800	hrs.	L	Fall Labor	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
520	hrs.	L	October Labor	.64	.64	.66	.66	.66	.66	.66	.66	.66	.66	.68	.68	.66	.66
880	hrs.	L	Winter Labor														
430	ac.	L	Stubble Land	1.	1.			1.	1.		1.	1.		1.	1.		1.
0	ac.	L	Irrigation Land														
140	ac.	L	Fallow Land			1.	1.			1.			1.			1.	
4000	$	L	Capital Supply	19.31	12.54	16.58	12.11	17.28	10.51	14.92	17.55	10.78	15.19	15.07	11.07	10.96	17.55
0	bu.	L	Wheat Supply	-23.90	-18.00	-28.56	-25.00										
236	ac.	L	Wheat Maximum	1.	1.	1.	1.										
0	bu.	L	Oat Supply					-44.26	-39.00	-55.76							
118	ac.	L	Oat Maximum					1.	1.	1.							
0	bu.	L	Barley Supply								-33.50	-24.00	-47.30				
118	ac.	L	Barley Maximum								1.	1.	1.				
88	ac.	L	Rye Maximum														1.
150	ac.	L	Rape Maximum														
150	ac.	L	Sunflower Maximum														
36	ac.	L	Field Peas Maximum														
118	ac.	L	Flax Maximum											1.	1.	1.	
12	ac.	L	Potato Maximum														
0	cwt.	L	Alfalfa Supply														
36	ac.	L	Alfalfa Maximum														
0	cwt.	L	Forage Supply														
0	cwt.	L	Silage Corn Supply														
0	bu.	L	Grain Corn Supply														
36	ac.	L	Grain Corn Maximum														
140	ac.	E	Summer-Fallow														
168	ac.	E	Irrigation Limit														
0	ac.-in.	L	Irrigation Water Supply														
0	times	L	Spring Irrigating														
0	times	L	Summer Irrigating														
0	times	L	Fall Irrigating														
0	bu.	L	Rye Supply														-27.77
0	ac.	L	Assignable Acreage Supply	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.
0	bu.	L	Wheat Quota Supply														
0	bu.	L	Oats Quota Supply														
0	bu.	L	Barley Quota Supply														
0	bu.	L	Rye Quota Supply														
0	bu.	L	Rapeseed Quota Supply														
0	bu.	L	Flax Quota Supply											9.22	8.20	11.	
0	$	L	Cash Generated	19.31	12.54	16.58	12.11	17.28	10.51	14.92	17.55	10.78	15.19	-11.11	-12.22	-20.38	17.55
0	$	E	Income Accounting Equality	19.31	12.54	16.58	12.11	17.28	10.51	14.92	17.55	10.78	15.19	-11.11	-12.22	-20.38	17.55

*L = less than, E = equals.

Table E-2 (continued)

Levels		Type* of Restraint	Restraints \ Obj. Function → / Activities →	RSD	RASFD	RAFFD	SNSFD	POSFD	PFFD	ASFD	ASD	SMFW	AFFD	SCSFD	GCSFD	FOSFD	WFI
3900	hrs.	L	Total Labor	3.71	3.30	3.45	3.74	37.40	3.33	2.95	2.68		3.39	5.20	5.64	1.61	4.77
1125	hrs.	L	Total Operator's Labor	.34	.30	.31	.34	3.40	.30	.27	.24		.31	.47	.51	.15	.43
700	hrs.	L	Spring Labor	1.10	1.00	1.12	1.12	4.00	.88	.12	-		.52	.88	.88	.12	1.47
1000	hrs.	L	Summer Labor	.27	-	-	.40	3.50	.27	1.22	1.22	2.31	1.22	.67	.67	-	.62
800	hrs.	L	Fall Labor	1.34	1.34	1.34	-	14.50	1.20	1.12	1.00		1.12	2.50	2.90	.34	1.61
520	hrs.	L	October Labor	.66	.66	.68	1.88	12.00	.68	.22	.22		.22	.68	.68	1.00	.64
880	hrs.	L	Winter Labor														
430	ac.	L	Stubble Land	1.	1.		1.	1.		1.	1.	1.		1.		1.	1.
0	ac.	L	Irrigation Land														
140	ac.	L	Fallow Land			1.			1.				1.				
4000	$	L	Capital Supply	15.19	18.50	15.45	16.14	69.74	11.36	13.34	10.14	4.77	12.84	19.64	20.47	7.85	21.55
0	bu.	L	Wheat Supply														-37.80
236	ac.	L	Wheat Maximum														1.
0	bu.	L	Oat Supply														
118	ac.	L	Oat Maximum														
0	bu.	L	Barley Supply														
118	ac.	L	Barley Maximum														
88	ac.	L	Rye Maximum	1.													
150	ac.	L	Rape Maximum		1.	1.											
150	ac.	L	Sunflower Maximum				1.										
36	ac.	L	Field Peas Maximum						1.								
118	ac.	L	Flax Maximum														
12	ac.	L	Potato Maximum					1.									
0	cwt.	L	Alfalfa Supply							-40.00	-34.		-48.				
36	ac.	L	Alfalfa Maximum							1.	1.		1.				
0	cwt.	L	Forage Supply													-40.	
0	cwt.	L	Silage Corn Supply											-132.			
0	bu.	L	Grain Corn Supply												-28.96		
36	ac.	L	Grain Corn Maximum												1.		
140	ac.	E	Summer-Fallow									1.					
168	ac.	E	Irrigation Limit														7.33
0	ac.-in.	L	Irrigation Water Supply														1.
0	times	L	Spring Irrigating														2.
0	times	L	Summer Irrigating														
0	times	L	Fall Irrigating														
0	bu.	L	Rye Supply	-36.81													
0	ac.	L	Assignable Acreage Supply	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.
0	bu.	L	Wheat Quota Supply														
0	bu.	L	Oats Quota Supply														
0	bu.	L	Barley Quota Supply														
0	bu.	L	Rye Quota Supply														
0	bu.	L	Rapeseed Quota Supply		26.04	27.50											
0	bu.	L	Flax Quota Supply														
0	$	L	Cash Generated	15.19	-35.92	-42.02	-21.71	-155.61	-32.20	13.34	10.14	4.77	12.84	19.64	20.47	7.85	21.55
0	$	E	Income Accounting Equality	15.19	-35.92	-42.02	-21.71	-155.61	-32.20	13.34	10.14	4.77	12.84	19.64	20.47	7.85	21.55

*L = less than, E = equals.

Table E-2 (continued)

Levels		Type* of Restraint	Obj. Function → / Activities → / Restraints	OFI	BFI	FXFI	RAFI	SNFI	POFI	PFI	AFI	CSFI	CGFI	FOFI	FCTI	SPTI	SUTI
3900	hrs.	L	Total Labor	4.77	4.77	4.77	4.77	5.19	40.77	4.99	7.99	7.81	9.04	4.06	38.64	.32	.32
1125	hrs.	L	Total Operator's Labor	.43	.43	.43	.43	.47	3.41	.71	.73	.71	.82	.37	3.86	.03	.03
700	hrs.	L	Spring Labor	1.47	1.47	1.47	1.47	1.47	3.91	1.47	.12	1.23	1.23	.12	19.32	.29	
1000	hrs.	L	Summer Labor	.62	.62	.62	.62	.80	3.82	.62	3.57	1.52	1.27	-			.29
800	hrs.	L	Fall Labor	1.61	1.61	1.61	1.61	-	14.40	1.43	2.00	3.33	4.70	1.57	19.32		
520	hrs.	L	October Labor					2.45	12.00	1.02	1.57	1.02	1.02	2.00			
880	hrs.	L	Winter Labor														
430	ac.	L	Stubble Land												168.		
0	ac.	L	Irrigation Land	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	-168.		
140	ac.	L	Fallow Land														
4000	$	L	Capital Supply	19.82	19.73	17.26	21.11	17.90	82.54	12.82	13.38	27.38	28.49	7.87	1275.95	.39	.39
0	bu.	L	Wheat Supply														
236	ac.	L	Wheat Maximum														
0	bu.	L	Oat Supply	-75.00													
118	ac.	L	Oat Maximum	1.													
0	bu.	L	Barley Supply		-50.00												
118	ac.	L	Barley Maximum		1.												
88	ac.	L	Rye Maximum														
150	ac.	L	Rape Maximum				1.										
150	ac.	L	Sunflower Maximum					1.									
36	ac.	L	Field Peas Maximum							1.							
118	ac.	L	Flax Maximum			1.											
12	ac.	L	Potato Maximum						1.								
0	cwt.	L	Alfalfa Supply								-88.						
36	ac.	L	Alfalfa Maximum								1.						
0	cwt.	L	Forage Supply											-80.			
0	cwt.	L	Silage Corn Supply									-306.4					
0	bu.	L	Grain Corn Supply										-51.88				
36	ac.	L	Grain Corn Maximum										1.				
140	ac.	E	Summer-Fallow												168.		
168	ac.	E	Irrigation Limit														
0	ac.-in.	L	Irrigation Water Supply	7.33	7.33	10.33	7.33	10.33	8.33	10.33	17.67	8.33	8.33	14.61			
0	times	L	Spring Irrigating	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	2.		-1.	
0	times	L	Summer Irrigating	2.	2.	3.	2.	2.	3.	3.	4.	3.	3.	7.			-1.
0	times	L	Fall Irrigating					1.						1.			
0	bu.	L	Rye Supply														
0	ac.	L	Assignable Acreage Supply	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.			
0	bu.	L	Wheat Quota Supply														
0	bu.	L	Oats Quota Supply														
0	bu.	L	Barley Quota Supply														
0	bu.	L	Rye Quota Supply														
0	bu.	L	Rapeseed Quota Supply				35.40										
0	bu.	L	Flax Quota Supply			20.											
0	$	L	Cash Generated	19.82	19.73	-39.54	-53.12	-53.14	-308.46	-96.08	13.38	27.38	28.49	7.87	1634.84	.39	.39
0	$	E	Income Accounting Equality	19.82	19.73	-39.54	-53.12	-53.14	-308.46	-96.08	13.38	27.38	28.49	7.87	1634.84	.39	.39

*L = less than, E = equals.

Table E-2 (continued)

Levels		Type* of Restraint	Restraints (Obj. Function → / Activities →)	FATI	FCSI	SPSI	SUSI	FASI	PCSI	PCTI	TRLD	WHQTR	OAQTR	BAQTR	RYQTR	RAQTR	FLQTR
3900	hrs.	L	Total Labor	.32	78.96	.07	.07	.07									
1125	hrs.	L	Total Operator's Labor	.03	7.89	.01	.01	.01									
700	hrs.	L	Spring Labor		39.48	.06											
1000	hrs.	L	Summer Labor				.06										
800	hrs.	L	Fall Labor	.29	39.48			.06									
520	hrs.	L	October Labor														
880	hrs.	L	Winter Labor														
430	ac.	L	Stubble Land		168.						-1.						
0	ac.	L	Irrigation Land		-168.						1.						
140	ac.	L	Fallow Land														
4000	$	L	Capital Supply	.39	2270.28	.08	.08	.08	1.04	.40							
0	bu.	L	Wheat Supply														
236	ac.	L	Wheat Maximum														
0	bu.	L	Oat Supply														
118	ac.	L	Oat Maximum														
0	bu.	L	Barley Supply														
118	ac.	L	Barley Maximum														
88	ac.	L	Rye Maximum														
150	ac.	L	Rape Maximum														
150	ac.	L	Sunflower Maximum														
36	ac.	L	Field Peas Maximum														
118	ac.	L	Flax Maximum														
12	ac.	L	Potato Maximum														
0	cwt.	L	Alfalfa Supply														
36	ac.	L	Alfalfa Maximum														
0	cwt.	L	Forage Supply														
0	cwt.	L	Silage Corn Supply														
0	bu.	L	Grain Corn Supply														
36	ac.	L	Grain Corn Maximum														
140	ac.	E	Summer-Fallow														
168	ac.	E	Irrigation Limit		168.												
0	ac.-in.	L	Irrigation Water Supply						-1.	-1.							
0	times	L	Spring Irrigating			-1.											
0	times	L	Summer Irrigating				-1.										
0	times	L	Fall Irrigating	-1.				-1.									
0	bu.	L	Rye Supply														
0	ac.	L	Assignable Acreage Supply									1.	1.	1.	1.	1.	1.
0	bu.	L	Wheat Quota Supply									-8.					
0	bu.	L	Oats Quota Supply										-20.				
0	bu.	L	Barley Quota Supply											-30.			
0	bu.	L	Rye Quota Supply												-20.		
0	bu.	L	Rapeseed Quota Supply													-40.	
0	bu.	L	Flax Quota Supply														-12.
0	$	L	Cash Generated	.39	2750.88	.08	.08	.08	1.04	.40							
0	$	E	Income Accounting Equality	.39	2750.88	.08	.08	.08	1.04	.40							

*L = less than, E = equals.

Table E-2 (continued)

Levels		Type of Restraint	Restraints \ Obj. Function → / Activities →	WNEMC	WNEPC	ONEMC	ONEPC	BNEMC	BNEPC	RNEMC	RNEPC	CNEMC	CNEPC	ANEMC	ANEPC	HNEMC
3900	hrs.	L	Total Labor													
1125	hrs.	L	Total Operator's Labor													
700	hrs.	L	Spring Labor													
1000	hrs.	L	Summer Labor													
800	hrs.	L	Fall Labor													
880	hrs.	L	Winter Labor													
4000	$	L	Capital Supply													
0	bu.	L	Livestock Capital Supply													
0	bu.	L	Wheat Supply	1.67	1.67											
0	bu.	L	Oat Supply			3.12	3.12									
0	bu.	L	Barley Supply					2.68	2.68							
0	cwt.	L	Alfalfa Supply											1.	1.	
0	cwt.	L	Forage Supply													1.
0	cwt.	L	Silage Corn Supply									1.78	1.78			
0	bu.	L	Grain Corn Supply							1.78	1.78					
0	bu.	L	Rye Supply													
0	megcal	L	NEM - Calf Req'ment	-95.		-80.		-84.		-80.		-95.		-55.		-54.
0	megcal	L	NEP - Calf Req'ment		-62.		-50.		-53.		-50.		-62.		-20.	
0	%	L	Protein - Calf Req'ment	-14.	-14.	-11.	-11.	-12.	-12.	-12.	-12.	-8.90	-8.90	-14.	-14.	-8.
0	%	L	Molasses - Calf Req'ment													
0	%	L	Urea - Calf Req'ment											-1.	-1.	-1.
0	%	L	Roughage - Calf Req'ment													
0	cwt.	E	Total Feed - Calf Req'ment	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.
0	megcal	L	NEM - Yearling Req'ment													
0	megcal	L	NEP - Yearling Req'ment													
0	%	L	Protein - Yearling Req'ment													
0	%	L	Molasses - Yearling Req'ment													
0	%	L	Urea - Yearling Req'ment													
0	%	L	Roughage - Yearling Req'ment													
0	cwt.	E	Total Feed - Yearling Req'ment													
1	unit	E	Feedlot Construction													
0	spaces	L	Winter Bld. Space Supply													
0	spaces	L	Summer Bld. Space Supply													
50	spaces	L	Winter Space - Hogs													
0	$	L	Cash Generated													
0	$	E	Income Accounting Equality													
0	%	L	Molasses (for Summer Yearling)													
0	%	L	Urea (for Summer Yearling)													
0	$	L	Cash Gen. by Winter Livestock													
0	calf	E	Calf Supply													
0	yearl.	E	Winter Yearling Supply													
0	yearl.	E	Summer Yearling Supply													
0	hog	E	Hog Supply													

Table E-2 (continued)

Levels		Type of Restraint	Restraints (Obj. Function → / Activities →)	HNEPC	SNEMC	SNEPC	BMMC	BMPC	BURAC	BURAY	BURASY	BMMSY	BMPSY	WNEMY	WNEPY	ONEMY
3900	hrs.	L	Total Labor													
1125	hrs.	L	Total Operator's Labor													
700	hrs.	L	Spring Labor													
1000	hrs.	L	Summer Labor													
800	hrs.	L	Fall Labor													
880	hrs.	L	Winter Labor													
4000	$	L	Capital Supply				1.70	1.70	5.00	5.00						
0	bu.	L	Livestock Capital Supply													
0	bu.	L	Wheat Supply											1.67	1.67	
0	bu.	L	Oat Supply													3.12
0	bu.	L	Barley Supply													
0	cwt.	L	Alfalfa Supply													
0	cwt.	L	Forage Supply	1.												
0	cwt.	L	Silage Corn Supply		1.	1.										
0	bu.	L	Grain Corn Supply													
0	bu.	L	Rye Supply													
0	megcal	L	NEM - Calf Req'ment		-24.		-65.									
0	megcal	L	NEP - Calf Req'ment	-19.		-11.		-41.								
0	%	L	Protein - Calf Req'ment	-8.	-230.	-230.	-8.	-8.								
0	%	L	Molasses - Calf Req'ment				-100.	-100.								
0	%	L	Urea - Calf Req'ment						-100.							
0	%	L	Roughage - Calf Req'ment	-1.	-1.	-1.										
0	cwt.	E	Total Feed - Calf Req'ment	-1.	-1.	-1.	-1.	-1.	-1.							
0	megcal	L	NEM - Yearling Req'ment									-65.		-95.		-80.
0	megcal	L	NEP - Yearling Req'ment										-41.		-62.	
0	%	L	Protein - Yearling Req'ment									-8.	-8.	-14.	-14.	-11.
0	%	L	Molasses - Yearling Req'ment													
0	%	L	Urea - Yearling Req'ment							-100.						
0	%	L	Roughage - Yearling Req'ment													
0	cwt.	E	Total Feed - Yearling Req'ment							-1.	-1.	-1.	-1.	-1.	-1.	-1.
1	unit	E	Feedlot Construction													
0	spaces	L	Winter Bld. Space Supply													
0	spaces	L	Summer Bld. Space Supply													
50	spaces	L	Winter Space - Hogs													
0	$	L	Cash Generated				1.70	1.70	5.00	5.00	5.00	1.70	1.70			
0	$	E	Income Accounting Equality				1.70	1.70	5.00	5.00	5.00	1.70	1.70			
0	%	L	Molasses (for Summer Yearling)									-100.	-100.			
0	%	L	Urea (for Summer Yearling)								-100.					
0	$	L	Cash Gen. by Winter Livestock								5.00	1.70	1.70			
0	Calf	E	Calf Supply													
0	Yearl.	E	Winter Yearling Supply													
0	Yearl.	E	Summer Yearling Supply													
0	Hog	E	Hog Supply													

Table E-2 (continued)

Levels		Type of Restraint	Restraints \ Obj. Function → / Activities →	ONEPY	BNEMY	BNEPY	RNEMY	RNEPY	CNEMY	CNEPY	ANEMY	ANEPY	HNEMY	HNEPY	SNEMY
3900	hrs.	L	Total Labor												
1125	hrs.	L	Total Operator's Labor												
700	hrs.	L	Spring Labor												
1000	hrs.	L	Summer Labor												
800	hrs.	L	Fall Labor												
880	hrs.	L	Winter Labor												
4000	$	L	Capital Supply												
0	bu.	L	Livestock Capital Supply												
0	bu.	L	Wheat Supply												
0	bu.	L	Oat Supply	3.12											
0	bu.	L	Barley Supply		2.68	2.68									
0	cwt.	L	Alfalfa Supply								1.	1.			
0	cwt.	L	Forage Supply										1.	1.	
0	cwt.	L	Silage Corn Supply												1.
0	bu.	L	Grain Corn Supply						1.78	1.78					
0	bu.	L	Rye Supply				1.78	1.78							
0	megcal	L	NEM - Calf Req'ment												
0	megcal	L	NEP - Calf Req'ment												
0	%	L	Protein - Calf Req'ment												
0	%	L	Molasses - Calf Req'ment												
0	%	L	Urea - Calf Req'ment												
0	%	L	Roughage - Calf Req'ment												
0	cwt.	E	Total Feed - Calf Req'ment												
0	megcal	L	NEM - Yearling Req'ment		-84.		-80.		-95.		-55.		-54.		-24.
0	megcal	L	NEP - Yearling Req'ment	-50.		-53.		-50.		-62.		-20.		-19.	
0	%	L	Protein - Yearling Req'ment	-11.	-12.	-12.	-12.	-12.	8.9	-8.90	-14.	-14.	-8.	-8.	-2.30
0	%	L	Molasses - Yearling Req'ment												
0	%	L	Urea - Yearling Req'ment								-1.	-1.	-1.	-1.	-1.
0	%	L	Roughage - Yearling Req'ment												
0	cwt.	E	Total Feed - Yearling Req'ment	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.	-1.
1	unit	E	Feedlot Construction												
0	spaces	L	Winter Bld. Space Supply												
0	spaces	L	Summer Bld. Space Supply												
50	spaces	L	Winter Space - Hogs												
0	$	L	Cash Generated												
0	$	E	Income Accounting Equality												
0	%	L	Molasses (for Summer Yearling)												
0	%	L	Urea (for Summer Yearling)												
0	$	L	Cash Gen. by Winter Livestock												
0	Calf	E	Calf Supply												
0	Yearl.	E	Winter Yearling Supply												
0	Yearl.	E	Summer Yearling Supply												
0	Hog	E	Hog Supply												

Table E-2 (continued)

Levels		Type of Restraint	Obj. Function → / Activities → / Restraints	SNEPY	BMMY	BMPY	CAFE	YEFEW	YEFES	HOGF	BCALF	BWYEAR	BSYEAR	BHOG	ACFL
3900	hrs.	L	Total Labor				12.54	8.69	3.52	1.54					
1125	hrs.	L	Total Operator's Labor				1.14	.79	.32	.14					
700	hrs.	L	Spring Labor						1.50						
1000	hrs.	L	Summer Labor						1.10						
800	hrs.	L	Fall Labor						.60						
880	hrs.	L	Winter Labor				11.4	7.9		1.4					
4000	$	L	Capital Supply		1.70	1.70									
0	bu.	L	Livestock Capital Supply				22.65	15.53		12.47	162.20	236.62		20.	
0	bu.	L	Wheat Supply												
0	bu.	L	Oat Supply							8.73					
0	bu.	L	Barley Supply												
0	cwt.	L	Alfalfa Supply												
0	cwt.	L	Forage Supply												
0	cwt.	L	Silage Corn Supply	1.											
0	bu.	L	Grain Corn Supply							2.80					
0	bu.	L	Rye Supply												
0	megcal	L	NEM - Calf Req'ment				847.								
0	megcal	L	NEP - Calf Req'ment				737.								
0	%	L	Protein - Calf Req'ment				440.								
0	%	L	Molasses - Calf Req'ment				200.								
0	%	L	Urea - Calf Req'ment				40.								
0	%	L	Roughage - Calf Req'ment				18.75								
0	cwt.	E	Total Feed - Calf Req'ment				40.								
0	megcal	L	NEM - Yearling Req'ment		-65.			659.	659.						
0	megcal	L	NEP - Yearling Req'ment	-11.		-41.		645.	645.						
0	%	L	Protein - Yearling Req'ment	-2.30	-8.	-8.		247.	247.						
0	%	L	Molasses - Yearling Req'ment		-100.	-100.		123.75							
0	%	L	Urea - Yearling Req'ment					24.75							
0	%	L	Roughage - Yearling Req'ment	-1.				17.46	17.46						
0	cwt.	E	Total Feed - Yearling Req'ment	-1.	-1.	-1.		24.75	24.75						
1	unit	E	Feedlot Construction												1.
0	spaces	L	Winter Bld. Space Supply				1.	1.							-50.
0	spaces	L	Summer Bld. Space Supply						1.	1.					-50.
50	spaces	L	Winter Space - Hogs												
0	$	L	Cash Generated		1.70	1.70	-239.64	-274.38	-274.38	-33.08	162.20	236.62	236.62	20.	621.18
0	$	E	Income Accounting Equality		1.70	1.70	-239.64	-274.38	-274.38	-33.08	162.20	236.62	236.62	20.	621.18
0	%	L	Molasses (for Summer Yearling)						123.75						
0	%	L	Urea (for Summer Yearling)						24.75						
0	$	L	Cash Gen. by Winter Livestock				-239.64	-274.38	15.53	-33.08			236.62		
0	Calf	E	Calf Supply				1.				-1.				
0	Yearl.	E	Winter Yearling Supply					1.				-1.			
0	Yearl.	E	Summer Yearling Supply						1.				-1.		
0	Hog	E	Hog Supply							1.				-1.	

Table E-2 (continued)

Levels		Type of Restraint	Restraints (Obj. Function → / Activities →)	BOAT	BBAR	HSPLA	HSULA	HFALA	HOCLA	RSTLD	BCCAP	BLVCAP	SWHTQ	SOAT
3900	hrs.	L	Total Labor			-1.	-1.	-1.	-1.					
700	hrs.	L	Spring Labor			-1.								
1000	hrs.	L	Summer Labor				-1.							
800	hrs.	L	Fall Labor					-1.						
520	hrs.	L	October Labor						-1.					
430	ac.	L	Stubble Land							-1.				
4000	$	L	Capital Supply (Cash)			1.75	1.50	1.50	1.75	8.00	-1.			
0	$	L	Livestock Capital Supply	.60	.88							-1.		
6000	$	L	Bor. Limit - Crop. Oper. Cap.								1.			
10000	$	L	Bor. Limit - Livestock Oper. Cap.									1.		
300	hrs.	L	Limit - Spring Labor Hire			1.								
400	hrs.	L	Limit - Summer Labor Hire				1.							
300	hrs.	L	Limit - Fall Labor Hire					1.						
220	hrs.	L	Limit - October Labor Hire						1.					
160	ac.	L	Limit on Land Rental							1.				
0	bu.	L	Wheat Supply										1.	
0	bu.	L	Oat Supply	-1.										1.
0	bu.	L	Barley Supply		-1.									
0	bu.	L	Rye Supply											
0	bu.	L	Grain Corn Supply											
0	cwt.	L	Alfalfa Supply											
0	$	L	Cash Generated	.60	.88	1.75	1.50	1.50	1.75	8.00	.08	.08	-1.48	-.58
0	$	E	Income Accounting Equality	.60	.88	1.75	1.50	1.50	1.75	8.00	.08	.08	-1.48	-.58
1	unit	E	Accounting Equality											
0	bu.	L	Wheat Quota Supply										1.	
0	bu.	L	Oat Quota Supply											1.
0	bu.	L	Barley Quota Supply											
0	bu.	L	Rye Quota Supply											
1	unit	E	Annual Fixed Overhead											

Table E-2 (continued)

Levels		Type of Restraint	Restraints (Obj. Function → / Activities →)	SBAR	SRYE	SWHTF	SALF	SGCOR	ANFC	T3	T4	T5	T6
3900	hrs.	L	Total Labor										
700	hrs.	L	Spring Labor										
1000	hrs.	L	Summer Labor										
800	hrs.	L	Fall Labor										
520	hrs.	L	October Labor										
430	ac.	L	Stubble Land										
4000	$	L	Capital Supply (Cash)										
0	$	L	Livestock Capital Supply										
6000	$	L	Bor. Limit - Crop. Oper. Cap.										
10000	$	L	Bor. Limit - Livestock Oper. Cap.										
300	hrs.	L	Limit - Spring Labor Hire										
400	hrs.	L	Limit - Summer Labor Hire										
300	hrs.	L	Limit - Fall Labor Hire										
220	hrs.	L	Limit - October Labor Hire										
160	ac.	L	Limit on Land Rental										
0	bu.	L	Wheat Supply			1.							
0	bu.	L	Oat Supply										
0	bu.	L	Barley Supply	1.									
0	bu.	L	Rye Supply		1.								
0	bu.	L	Grain Corn Supply					1.					
0	cwt.	L	Alfalfa Supply				1.						
0	$	L	Cash Generated	-.86	-1.	-.89	-.91	-1.41	1959.20	8.4	173.9	393.1	647.9
0	$	E	Income Accounting Equality	-.86	-1.	-.89	-.91	-1.41	1959.20	3000.	4000.	5000.	6000.
1	unit	E	Accounting Equality							1.	1.	1.	1.
0	bu.	L	Wheat Quota Supply										
0	bu.	L	Oat Quota Supply										
0	bu.	L	Barley Quota Supply	1.									
0	bu.	L	Rye Quota Supply		1.								
1	unit	E	Annual Fixed Overhead						1.				

Table E-2 (continued)

Levels		Type of Restraint	Restraints (Obj. Function → / Activities →)	T7	T9	T11	T13	T15	T17	T19	T21	T23	1. TRCASH
3900	hrs.	L	Total Labor										
700	hrs.	L	Spring Labor										
1000	hrs.	L	Summer Labor										
800	hrs.	L	Fall Labor										
520	hrs.	L	October Labor										
430	ac.	L	Stubble Land										
4000	$	L	Capital Supply (Cash)										
0	$	L	Livestock Capital Supply										
6000	$	L	Bor. Limit - Crop. Oper. Cap.										
10000	$	L	Bor. Limit - Livestock Oper. Cap.										
300	hrs.	L	Limit - Spring Labor Hire										
400	hrs.	L	Limit - Summer Labor Hire										
300	hrs.	L	Limit - Fall Labor Hire										
220	hrs.	L	Limit - October Labor Hire										
160	ac.	L	Limit on Land Rental										
0	bu.	L	Wheat Supply										
0	bu.	L	Oat Supply										
0	bu.	L	Barley Supply										
0	bu.	L	Rye Supply										
0	bu.	L	Grain Corn Supply										
0	cwt.	L	Alfalfa Supply										
0	$	L	Cash Generated	923.8	1544.1	2201.15	3040.13	4017.1	5129.1	6312.88	7564.88	8815.88	1.
0	$	E	Income Accounting Equality	7000.	9000.	11000.	13000.	15000.	17000.	19000.	21000.	23000.	
1	unit	E	Accounting Equality	1.	1.	1.	1.	1.	1.	1.	1.	1.	
0	bu.	L	Wheat Quota Supply										
0	bu.	L	Oat Quota Supply										
0	bu.	L	Barley Quota Supply										
0	bu.	L	Rye Quota Supply										
1	unit	E	Annula Fixed Overhead										

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