AN ECONOMIC FEASIBILITY STUDY OF GRAIN CORN PRODUCTION IN SOUTH CENTRAL MANITOBA - A MICRO ANALYSIS

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by

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ABSTRACT

In this study, South-Central Manitoba was described as the area comprised of the municipalities of Morris, Roland, Thompson and Dufferin, where both the soil and climatic factors are favourable for grain corn production. The purpose of the study was to investigate how grain corn competes with other crops in the context of maximizing farm income. The conceptual and computational tool employed by the study was linear programming.

A case farm was selected for the study. The case farm was an established crop producing unit, with the necessary complement of row-crop machinery for corn production. By studying the set of available resources on the case farm in 1971, a detailed analysis of the optimum combination of enterprises was performed.

The results obtained show that grain corn competed with other crops and significantly contributed to maximization of farm income at a price of $1.60 per bushel for corn. At prices below $1.60 but, above $1.10 per bushel for corn, grain corn was found to be profitable in the cropping program. But, at a price of $1.10 and below, per bushel for corn it was found that grain corn was no longer profitable and should not be included in the cropping program. Grain corn provided an alternative crop for non-quota production of both cash and feed crops. The extent to which grain corn could be included in any cropping program was limited by the available supply of labor during the critical planting period.

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INTRODUCTION

1. PATTERN OF CROP PRODUCTION IN SOUTH-CENTRAL MANITOBA

For the purpose of this study South-Central Manitoba was identified as the area comprising the municipalities of Morris, Roland, Thompson and Dufferin. The farms in the area produce a variety of crops and livestock. Among the major crops grown are wheat, oats, barley, rye and flaxseed as evidenced by Table I, while the livestock raised are cattle, sheep, pigs and poultry as presented in the Appendix, Table A.5.

Observing Table I, it is noted that in 1956 more acres were utilized for wheat production than for any other crop, followed by oats, flaxseed, barley, hay and fodder crops and a small acreage in rye. This pattern of cropland utilization carried through 1961, except for the addition of a small acreage in rapeseed, by 1966 the pattern changed slightly with oil seeds occupying a larger acreage than the coarse grains.

Between the period 1956 and 1961, wheat acreage in the area increased by 18.8 per cent, oats by 24.5 per cent, flaxseed by 7.5 per cent whereas there was a downward trend in the acreage of barley and rye with a decrease of 85.7 per cent and 35.1 per cent respectively, as evidenced by Table II. Also, between 1961 and 1966 the acreages in wheat and oats continued to increase but, at a decreasing rate, that is, 2.9 per cent and 9.8 per cent, respectively. Although there was an

TABLE I

CROP ACREAGES IN SOUTH CENTRAL MANITOBA 1956-1966*

Year	Munici-pality	Wheat	Oats	Barley	Rye	Flax Seed	Mixed Grains	Tame Hay	Rape Seed	Corn for Ensilage	Other Fodder Crops	Potatoes
						-- acres --						
1956	Morris	62.921	37,881	20,323	330	33,202	2,143	6,320		163	724	52
	Roland	23,900	30,909	16,265	599	28,423	2,099	5,073		649	979	607
	Thompson	24,571	16,454	11,352	740	5,856	595	3,588		578	284	41
	Dufferin	30,823	40,643	11,611	1,524	17,695	2,899	14,584		1,622	1,921	424
	Total	142,215	125,887	59,524	3,193	85,176	7,736	29,565		3,012	3,908	1,124
1961	Morris	74,761	36,194	4,033	265	39,457	2,946	15,306	300	259	663	30
	Roland	28,852	12,792	663	70	22,388	864	3,067	245	959	173	46
	Thompson	29.064	13,702	1,745	553	8,209	2,430	5,248	145	938	829	32
	Dufferin	36,303	32,365	2,035	1,184	21,547	6,148	12,393	283	2,794	801	1,111
	Total	168,980	95,053	8,476	2,072	91,601	12,388	36,014	973	4,950	2,466	1,219
1966	Morris	74,106	34,067	14,415	119	53,203	2,445	18,705	2,498	113	81	25
	Roland	30,340	11,156	5,222	55	27,056	556	1,906	1,225	432	129	9
	Thompson	30,063	13,021	5,618	465	13,202	1,335	4,674	508	787	116	18
	Dufferin	39,453	27,481	6,975	886	35,894	4,418	12,664	6,475	2,152	807	1,209
	Total	173,962	85,725	32,230	1,525	129,355	8,754	37,949	10,706	3,484	1,133	1,261

*Source: 1956, 1961 and 1966 Census of Canada Agriculture, Manitoba.

TABLE II

PERCENTAGE CHANGE IN CROP ACREAGE IN SOUTH-CENTRAL MANITOBA BETWEEN 1956 AND 1961 AND BETWEEN 1961 AND 1966

Crops	1956-1961	1961-1966
	----- per cent -----	
Wheat	18.8	2.9
Oats	24.5	9.8
Barley	-85.7	280.0
Rye	-35.1	-26.4
Flaxseed	7.5	41.2
Mixed Grains	60.1	-29.3
Tame Hay	21.8	5.4
Rapeseed	∞	1000.3
Corn for ensilage	64.3	-29.6
Other fodder crops	-36.9	-54.1
Potatoes	12.2	3.4

increase of 280 per cent in barley acreage, between 1961 and 1966, the 1966 barley acreage was less than the 1956 acreage (32,230 acres of barley in 1966 as against 59,524 acres of barley in 1956); the big increase was due to the low acreage seeded to barley in 1961. Flaxseed also enjoyed an increase of 41.2 per cent and rapeseed increased from 973 acres to 10,706.

Table III is presented to show the percentage of total cultivated acreage alloted to each of the major crops grown in 1966. It

TABLE III

1966 CROP DISTRIBUTION AS PERCENTAGE OF CULTIVATED ACRES IN SOUTH-CENTRAL MANITOBA

Municipality	Wheat	Oats	Barley	Rye	Flax Seed	Mixed Grains	Tame Hay	Rape Seed	Corn for Ensilage	Other Fodder Crops	Potatoes
	---- per cent ----										
Morris	37.09	17.05	7.22	0.06	26.63	1.22	9.36	1.25	0.06	0.04	0.01
Roland	38.85	14.29	6.69	0.07	34.65	0.71	2.44	1.57	0.55	0.17	0.01
Thompson	43.07	18.65	8.05	0.67	18.91	1.91	6.7	0.73	1.13	0.17	0.03
Dufferin	28.5	19.85	5.04	0.64	25.93	3.19	9.15	4.68	1.55	0.58	0.87

is noted that wheat occupied the most acreage, followed by flaxseed, oats, barley, rapeseed and rye excluding hay and fodder crops. The production pattern in the area has not changed very much over the years, but farmers have continuously varied the acreage planted to the various crops in order to adjust their production to changes in market demand, price fluctuations and changes in government policies.

Also, farmers in the past few years in an attempt to stabilize income - especially when faced with the above mentioned changes in government policies and fluctuations in market prices - have directed their attention toward raising livestock, growing special crops such as rapeseed, sunflowers, peas, buckwheat, grain corn and vegetable crops. The establishment of the distillery at Gimli created a demand for grain corn and as a result some farmers in South-Central Manitoba, where the climatic conditions are suitable for grain corn production have availed themselves of this new market opportunity.

11. THE NATURE AND SCOPE OF THE PROBLEM

It is generally assumed that a farm manager's economic objective is to use the resources of land, labour and capital at his disposal to produce the largest profit. This means that the resources must be efficiently allocated into the combination of different enterprises that will achieve the objective.

Many farmers especially those growing grains have been faced with the problems of surplus production and quota restrictions on deliveries which have forced them to search for alternative crops in order to fully utilize their resources and maintain their net income position.

The production of grain corn offers an opportunity to produce a non-quota crop with a ready market at the Gimli distillery. The available market statistics for the Gimli operation estimates an annual requirement of 1.2 million bushels of grain corn. Manitoba supplied 0.235 million bushels of this demand in 1971. This shows that there is tremendous scope for expansion of grain corn production in Manitoba if Manitoba farmers are to capture the greater part of this home market.

The feasibility of grain corn production in Manitoba has been studied by the Manitoba Corn Committee and some of their observations are as follows:

> the use of improved hybrids, adequate use of fertilizer, higher plant populations per acre and the economical use of herbicides have contributed to reducing the risks and increasing yields. Improvements in machinery have, in effect revolutionized methods of growing, harvesting and subsequent handling of the crop, greatly improving the timeliness of operations and reducing the labour costs involved in producing crops of good quality.[1]

Given that the Corn Committee have said that grain corn production technique has vastly improved, then the general problem is to find the competitive nature of grain corn to other crops in the use of farm resources and the consequent effect on the farmer's net income. In the light of the above, our specific interest will be directed to South-Central part of Manitoba, where local soil and climatic conditions

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[1]Manitoba Corn Committee, Field Corn in Manitoba (Publication No. 428), p. 1.

are favourable for the production of grain corn that meets the quality criteria of the Gimli market - that is:

1. minimum bushel weight of 56 pounds;
2. minimum grade of number 2;
3. maximum of 14 per cent moisture;
4. must not be dried with oil; and
5. corn must be free of any foreign or noxious odours.

111. OBJECTIVES

The study is intended to provide a planning guide to a crop producer who wants to include grain corn production in his cropping program.

The present characteristics of the crop industry indicate a need for information on how limited farm resources can be more efficiently organized to produce a combination of enterprises that will maximize farm net income and improve the cash flow position of the farm business.

The major part of the study is devoted to a case farm, which is an already established crop farm, with the necessary complement of row-crop machinery and equipment for corn production. The case farm also has a large investment in both fixed and operating capital. The objectives with regard to the study are as follows:

1. to determine the optimum combination of the various crops grown with the available resources on the case farm in 1971, with a view to determine how best to organize the farm business and at the same time examine how grain corn competes with other crops;

2. to observe how an increase in the cost of drying corn adds to corn production costs and affects the optimum solution in 1;
3. to determine the effect of varying the quantity of grain corn marketed through Gimli on the optima obtained in 1 and 2, thereby determining how grain corn competes with the other crops when price and quality are varied;
4. to examine the optimum solution in 2 when a portion of the grain corn crop fails to meet the quality standards set by the Gimli plant, while at the same time the feed industry does not provide an alternate market; and
5. to perform a sensitivity analysis on 1.

IV. DESIGNATION OF HYPOTHESES

A hypothesis may be defined as follows:

> A statement is functioning as a hypothesis if it is taken as a premise, in order that its logical consequences can be examined and compared with facts that can be ascertained by observation.[2]

The first step towards tackling a research program should be the formulation of the problem in as definite or specific terms as possible, that is, a working or test hypothesis.[3]

Generally a good hypothesis reflects one's experience, as well

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[2] W. Salmon, Logic, "Foundations of Philosophy Series" (New York: Prentice-Hall, inc., 1963), p. 77.

[3] W. Gee, Social Science Research Methods, (Appleton-Century-Crofts inc. 1950), p. 194.

as one's creative imagination, coupled with known facts. In the light of the above, the initial hypotheses may be designated thus:

1. with good market opportunities and optimum physical conditions, grain corn can compete with the other conventional crops;
2. if grain corn is able to compete with the other crops, then it can play a significant role in maximizing farm income; and
3. the amount of labour available at planting time limits the number of acres of corn that can be included in any cropping program.

V. METHODOLOGY

The conceptual and computational tool used in this study was linear programming. The static or conventional model was used to determine the optimum combination of enterprises that would maximize the income of the farmer, subject to certain restraints.

The linear programming method is particularly suited to this study because:

1. it allows us to simulate the planning environment of the case farm; and
2. it further helps us to determine a single optimum plan given the set of resources present on the case farm. Hence it provides an orientation on how the farm business should be organized over time.

The procedure followed in this study was to select a case farm, where grain corn was one of the enterprises and to identify the available resources and other planning restraints. Both input and output coefficients were calculated for the various enterprises on the case farm from the farm record and accounts and other sources. The costs as well as the returns for the different enterprises were computed. The linear programming technique was then applied in order to determine the optimum combination of enterprises.

V1. THE CASE METHOD

The case method was used in this study because data were more readily available and time constraints did not permit a study to be made of all grain corn producers nor a representative sample to be taken. In this respect, an accurate case study is "always a true record of what occurs, while statistical generalization (from a sample population) except in those instances, when all included cases are identified, is only an abstract approximation."[4] It should be noted that while justifying the case method approach for the purpose of this study, both the case and the statistical methods are interdependent and complementary.

The established practice in a case study approach is to select a case farm (in this study, a large farm, where crop production was the sole business) and perform a detailed analysis, ensuring that doubtful facts are not allowed to go unchallenged.

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[4]Gee, op. cit., p. 233.

While any conclusions reached by this study will be, in the main, peculiar to the case farm, however, they may be applicable to other farms with similar objectives. The conclusions can serve as a source of information to other farmers of similar interest, but substantial modification and careful judgment may be necessary in order to be able to apply the information beyond the case farm.

V11. SOIL AND CLIMATIC CHARACTERISTICS OF THE STUDY AREA[5]

The study area is located in South-Central Manitoba. The major soil associations are: Altona, Almasippi, Red River, Morden, Gretna and Sperling. Each of these soil associations have a smooth, level to slightly undulating topography. The major difference between the different soil groupings lies in the texture. Although Altona, Morden and Red River can be classified as well drained soils, yet Morris and Osborne associates of the Red River association are poorly drained.

The different soil associations can further be broken down into light sandy loams, fine loams, silty clay and heavy textured clay. This study is mainly interested in the soil groups which fall between the light sandy loams and clay loams because they are best suited to grain corn production within the area. The total acreage envisaged

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[5]J. H. Ellis and Wm. H. Shater, Report of Reconnaissance Soil Survey of South-Central Manitoba, (Winnipeg, Manitoba Department of Agriculture, 1943), pp. 1-49.

as a result of this classification were as follows:

Altona light sandy loams	64,515 acres
Altona fine loams	50,996 acres
Myrtle clay	40,477 acres
Morden silty clay	26,838 acres
Total	182,826 acres

The average annual precipitation is 18.35 inches with most of the precipitation falling between the months of April to November. The mean temperature during the months of April to October is above freezing and on the average is 56.81°F (degree Fahrenheit).

The soil and climatic characteristic of the area have been utilized to produce a great variety of crops. If grain corn production is competitive with other crops then we could anticipate a substantial expansion in acreage planted to corn especially if the product can be marketed at premium prices to the Gimli distillery.

CHAPTER II

PHYSICAL FACTORS AFFECTING CORN PRODUCTION IN MANITOBA

The production of corn is not a new activity in Manitoba. Historical records show that corn has been grown for at least 50 years. The acreage has, however, varied considerably from a few hundred acres in the early years (1920-1930) to about 100,000 acres at the present time. Although the greater portion of corn produced was used for silage, yet grain corn was not completely neglected. Between 1950 and 1965 the grain corn acreage varied between 3,300 acres to 30,000 acres.[1]

The Manitoba Corn Committee described the corn varieties first grown in Manitoba in the following way:

> The first corn grown included early varieties of the flint and dent types. The early flint varieties, Gehu, Quebec 28, Gaspe, Howes' Alberta, Longfellow, Falconer and others, were leafy and had fine stalks with the ears borne very close to the ground. They were low yielding and not suited to mechanical harvesting. North-Western Dent, Minnesota 13 and Golden Glow, popular varieties of early dents, were taller growing than the flints and somewhat later maturing. They bore their ears high enough to make mechanical harvesting feasible, but were subject to lodging, uneven maturity and low grain yields.[2]

Agronomic research has developed earlier maturing hybrids which have been found suitable to Manitoba conditions. They are generally high yielding with desirable qualities and will mature in all years except

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[1]Manitoba Corn Committee, op. cit., p. 1.

[2]Ibid.

when the growing season (May-October) is very cool.[3]

This study is particularly interested in the economics of grain corn production, despite the fact that corn can be grown for silage purposes. This chapter will review the physical factors affecting grain corn production in Manitoba and also examine the production practices employed by the case farm selected for this study. Emphasis will be focused on those physical factors that are important if the production of grain corn is to meet the specified conditions of the Gimli market. The Gimli market is defined as the Gimli distillery which uses grain corn as an input factor in the production of grain alcohol.

Climate, Soils and Fertilizer

Corn is a warm season crop, requiring a relatively high temperature for optimum growth. It has been found that the most important factor limiting the production of corn in Manitoba is temperature. Generally, moisture and sunshine are adequate.

If early maturing hybrids are planted, the minimum frost-free period for grain corn production is 110 days. The most important factor during the growing season is temperature. Temperature affects the length of the period necessary for maturity. The Manitoba Corn Committee has classified areas suitable for grain corn production on the basis of accumulation of the heat units - in degree days - above the minimum temperature required for germination and growth, which is 50°F. In summing up therefore a minimum of at least 2,200 corn heat

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[3]Ibid.

units in degree days is required to produce a good crop of grain corn.[4]

From the attached heat unit map in Figure 1, we find that the area to which attention is directed in this study - Carman, Morris, Morden and Altona have on the average a corn heat unit of 2,400 during the growing season. Hence in this area one of the necessary physical conditions for optimum grain corn production is satisfied.

Although climate has been identified and described as one of the major factors in grain corn production in Manitoba, yet the importance of soils cannot be overlooked. A good soil recommended for corn production should be porous and friable, with a good supply of organic matter. Such a soil can hold moisture without becoming waterlogged. Hence soil suitable for grain corn production in Manitoba would be one having a sandy loam texture. Grain corn can be grown satisfactorily on clay soils with good internal aeration, good surface drainage, and adequate fertilizer, but the big problem is accessibility during periods of excess rainfall, for the purpose of cultural weed control. Regardless of texture or the climatic zone, grain corn production is not recommended for either poorly drained or saline soils.[5]

Apart from the two factors so far dealt with, profitable corn production may be prohibited by low levels of fertility. Generally, corn is planted on stubble land and responds well to fertilizer. The best

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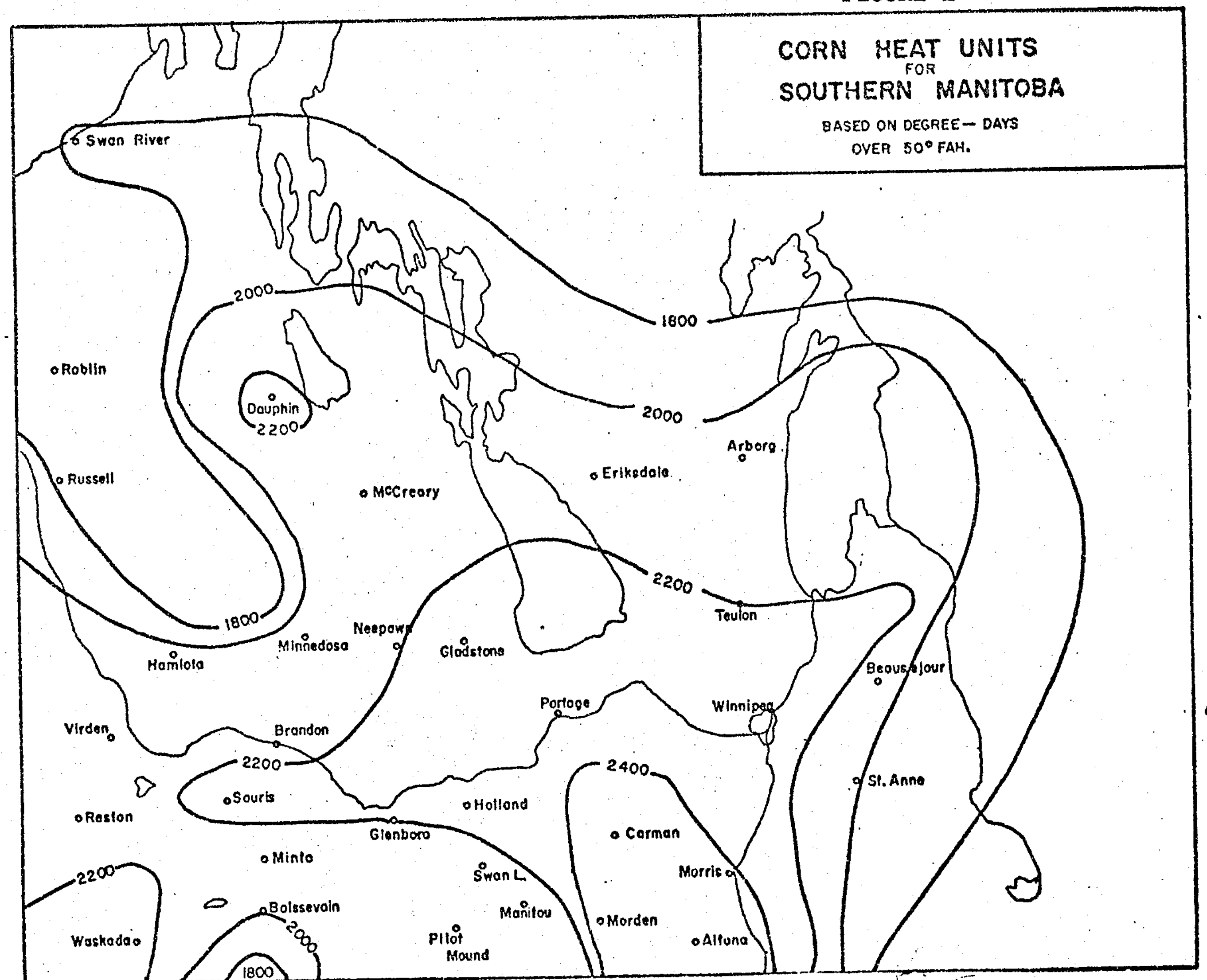
[4]Ibid., p. 2.

[5]Manitoba Agronomists Conference, 1972 Field Crop Recommendations for Manitoba, (Winnipeg: M.D.A., Publication Branch, 1972), pp. 19-20, Manitoba Corn Committee, op. cit., p. 4 and Harold D. Hughes and Edwin R. Henson, Corn Production (New York: The Macmillan Co., 1965), pp. 219-221.

FIGURE 1



*Source: Manitoba Corn Committee, op. cit., p. 2.

method of determining the amount of fertilizer input necessary for corn production is by soil testing, whereby the actual amount of nitrogen, phosphorous and potash needed are estimated.

For a general fertilizer recommendation see Table IV below where the requirements for each type of soil are specified.

TABLE IV

GENERAL FERTILIZER RECOMMENDATION FOR CORN TO BE GROWN ON STUBBLE LAND OR GRASS BREAKING[6]

Soil type	Nitrogen(N)	Phosphate(P_2O_5)	Potash(K_2O)
	- - - pounds per acre - - -		
Sands - Sandy Loams	40-60	20-30	25-35
Loams - Clays	40-60	20-30	0

The practice on the case farm was to use 100 pounds of nitrogen, 50-60 pounds of phosphorous and 15-20 pounds of potash per acre. The method of application was sidebanding the phosphorous, potash and 10-15 pounds of nitrogen with the seed. The remaining nitrogen in the form of anhydrous ammonia was ploughed in or applied before or after seeding.

Hybrid Selection and the Place of Corn in the Rotation

Many corn hybrids are sold in Canada but only a few may

[6]Manitoba Agronomist Conference, ibid., p. 20.

be adapted to any one area or region. The main criterion for selecting a hybrid for Manitoba conditions should be early maturity so as to avoid the possibility of damage by early fall frosts.

In view of the fact that no hybrid is going to excel in all of the desired characteristics, a grower should carefully select those hybrids that are particularly suited to local conditions. In this respect, it may be suggested that two or more hybrids may be grown on a small experimental scale to test their performance. On the basis of their performance a preference list should be established. Such a list must be constantly reviewed as new hybrids are developed and produced.

Table V is a list of corn varieties arranged in order of maturity as indicated by moisture content at harvest time. The hybrids grown on the case farm were Pride 116, Trojan M.70, Northrup King PX 417 and two varieties of Stewart, 2300 and 2408. The advantage of growing several varieties was that these hybrids have staggered maturity dates, thereby ensuring that harvesting was spread over a period of time and also reducing the risk of a total loss, due to early fall frost.

The place of corn in the rotation is very flexible. It can be planted at any place in the rotation, provided that adequate fertilizer is used and weeds are controlled. Corn can be used to replace fallow in a three or four year rotation, with small grains still performing as well after corn as they normally do after fallow. The other advantages of replacing fallow with corn are:

1. wind erosion control;
2. snow retention; and
3. replacement of fallow by a cash crop.

TABLE V

Performance of Corn Hybrids
Morden, Winnipeg and Brandon 1970-71[7]

Variety	Days to 50% silk	Root lodg. (1-5)	Test weight (lbs.)	Bus./ acre	Mois- ture %	Tons dry matter per acre	Total plants mois. %
Recommended for grain and silage							
Morden 88	65	3	64	71	20	4.49	58
Morden 67	66	3	63	86	22	4.60	62
Morden 7G*	67	2	62	94	22	-	-
Pride R102*	68	1	63	92	23	-	-
Trojan M70*	65	1	62	92	23	-	-
United 106	69	2	59	98	24	-	-
Stewart 3309	68	2	62	85	25	-	-
Stewart 2408*	67	1	64	99	26	-	-
Dawson M405*	68	1	60	106	26	-	-
Dekalb 007	70	2	60	93	26	-	-
Pride 116	67	1	63	93	26	5.06	64
Pride R101	70	1	62	90	26	5.10	66
Stewart 2605	70	2	60	84	26	5.23	68
Warwick SL209	70	3	60	86	26	5.20	66
N. King PX417	69	1	61	95	28	5.43	64

Ratings 1-5; 1 is best, 5 poorest.

*Recommended for the first time in 1972.

[7] Manitoba Agronomists Conference, <u>1972 Field Crop Recommendations for Manitoba</u>, (Winnipeg: M.D.A., Publication Branch, 1972), p. 19.

Corn is compatible with most crops in a rotation with the exception of barley. Corn and barley are susceptible to the same types of disease, therefore they should be separated in the rotation.[8]

Planting Practices[9]

Soil temperatures above 50°F are required for corn to germinate and this temperature does not generally occur until about May 15 in Manitoba. Hence, the recommended optimum time for planting corn is between May 15 and May 25. It is always advisable to plant early because the risk of fall frost increases for each additional day delay in planting after May 25. Earlier plantings do produce excellent results if weed control can be maintained. The general practice on the case farm was to plant during the first week in May.

Depth of seeding is a planting practice that affects the speed at which the seed corn germinates. Seed corn should be placed in close contact with warm moist soil. This allows for early emergence and also serves as an insurance against soil born diseases, insects and encrusted soil. It is suggested that the seed should be well covered for a good protection against rodents, birds and surface drying. The general recommendation is for a seeding depth of between one and two inches, (the case farm seeded at a depth of one and one half inches), depending

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[8] Manitoba Corn Committee, op. cit., p. 3.

[9] Manitoba Corn Committee, op. cit., pp. 6-8; Manitoba Agronomist Conference, ibid., p. 20 and Hughes and Henson, op. cit., pp. 225-229.

on soil moisture content.

Seeding rates are another important practice to consider. The water holding capacity of the soil and the amount of fertilizer being applied are two prime factors in determining the seeding rate. A general recommendation is for a population of between 18,000 and 30,000 plants per acre. The higher rates in this range are recommended for soils with good structure and high water holding capacity, while the lower rates will be found adequate for soils with less favourable physical properties (structure and water holding capacity). The fertilizer applied must also reflect the population desired (higher population requires a greater amount of fertilizer than a low population).

We have so far dealt with the seeding time, seeding depth and the seeding rate, now we should examine the different methods of planting corn. Three methods of planting corn have been examined in Manitoba, they are:

1. check row planting;
2. drilling; and
3. hill dropping.

In experiments carried out at Morden, Brandon and Winnipeg, it was found that drilling with a corn planter at uniform spacing gave the highest yields per acre, followed by hill dropping, while check row planting gave the lowest yields.[10] In the light of the above, the recommended practice for planting corn is drilling with a corn planter

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[10]Manitoba Corn Committee, op. cit., p. 7

at uniform spacing. Corn planters are essential equipment in order to do a good planting job. They are generally equipped with a fertilizer attachment which places the fertilizer in a band just slightly below and to the side of the seed. The corn planters are available in two-row, four-row, six-row and eight-row types and the grower is left with an ample choice.

Weed, Diseases and Insect Control[11]

In view of the fact that weeds reduce yield more than any other factor under the farmer's control, an efficient weed control program is essential for successful corn production. When the weeds are just germinating and are thread-like in form (especially when the corn is about six inches tall), the most effective implements for weed destruction are (i) the spike-tooth harrow, (ii) the finger weeder and (iii) the rotary hoe. When the corn reaches a height over six inches, a row cultivator should be used. It should be noted however that excess cultivation of corn (more than necessary) for weed control purposes usually leads to a decrease in yield. Chemical weed killers may also be used for the purpose of controlling weeds. The following chemicals may be found useful, 2,4-D amine, Avadex, MCPA, Antracine and Dicambe + 2,4-D + Mecroprop (Banvel 3 or kil-mor). Treatment with 2,4-D, MCPA or Banvel after the emergence of weeds will control the broad-leaved weeds successfully, while Avadex and Atracine + oil are very effective for the control of wild oats and green foxtail.

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[11]Manitoba Corn Committee, ibid., pp. 8-11, Manitoba Agronomist Conference, ibid., p. 21 and Hughes and Henson, ibid., pp. 229-234.

The case farm uses Atracine + oil and Banvel for band spraying weeds. This operation is performed twice followed by a row cultivator to control weeds between the rows.

The most dreaded disease of corn in Manitoba is stalk rot. It may cause an economic loss, because the disease weakens the plant, thereby causing it to break over, before harvesting. The causal agent responsible for the disease is soil borne and therefore present in most soils. It is however prevalent during periods of severe stress caused by drought and prolonged cool weather. The most effective control is to plant resistant hybrids.

The only insect infection of note is the European Corn Borer. Generally speaking they are prevalent during most of the growing season. They may be controlled by spraying insecticides like Sevin, but it has been found that during most seasons the cost of spraying may be higher than the losses suffered as a result of the corn borer. The damage is always in the form of weakening the stalk and causing it to break over.

Harvesting and Storage of Grain Corn[12]

When the moisture content of the field corn is about 35 per cent it is fit for harvesting. But for the purpose of picking and shelling or straight combining, where artificial drying is required for safe storage of the grain, a moisture content of about 30 per cent is advisable at harvesting time. However, in terms of harvesting efficiency,

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[12] Manitoba Corn Committee, ibid., pp. 10-11 and Hughe's and Henson, op. cit., pp. 231-234.

a lower moisture content of about 25-27 per cent is necessary.

A number of factors are taken into consideration in order to select appropriate machinery for harvesting corn. They are:

1. amount of corn to harvest;
2. available farm machinery;
3. available storage and drying facilities and
4. other crops planted on the farm which could lead to efficient use of harvesting, drying and storage facilities.

If the corn acreage is less than 30 acres, an economic harvesting method is custom hiring. If however the corn acreage is more than 30 acres, then the operator may consider selecting from the four different types of machines enumerated below for the purpose of picking and shelling corn:

1. a two-row mounted picker with a trailing sheller;
2. self propelled picker sheller. This is quite efficient and economical as it harvests the crop with minimum loss. The disadvantage is that it is only suited to grain corn and not to any other crop. Hence its purchase is only justified when the corn acreage is large;
3. self propelled combine equipped with a two-row or four-row corn header. This is more economical especially for grain growers, as it can be used for corn harvesting as well as other grains; and
4. self-propelled combine equipped with sunflower stripper. This can do a speedy job on the field but losses are greater than in (3) above.

The ideal combine speed should be between two and one quarter to two and one half miles per hour. Proper speed of travel together with appropriate cylinder adjustment are necessary for efficient combining.

Since the Gimli distillery requires that the moisture content of the grain corn be reduced to about 14 per cent for the purpose of safe storage, after harvest drying of corn is essential. Two drying methods have been used with success in Manitoba (a) natural air and (b) heated air. Heated air is recommended to any farmer contemplating a new drying set up because it is the most practical.

The case farm begins harvesting around October 1, when kernel moisture is about 25 per cent. Before drying, the grain is cleaned to remove cracked kernels and dust in order to upgrade the quality and to improve the efficiency of drying. The drying is done at 140°F, after which the corn is allowed five or six hours to cool.

We have established and discussed the agronomic factors affecting grain corn production in Manitoba. But crop farmers usually diversify production so as to insure against possible hazards associated with a mono-cropping program. In view of this we shall now direct our attention to economic theory of production as it relates to the optimum combination of enterprises.

CHAPTER III

OPTIMUM COMBINATION OF ENTERPRISES

The economic aspects of crop production and/or livestock production have always been important considerations in the maximization of farmer's returns. In this respect, a thorough economic analysis of the capital, labor, land, management and other resources at a farmer's command, with a view to arriving at an economic balance in production activities will be a fruitful exercise for a farmer. A brief consideration of the production theory will suggest how enterprises may be combined in order to maximize profit.

The procedure in this Chapter is first to review the concept of marginality and how it relates to production theory and enterprise combination. The second part will present and evaluate two approaches that may be used in solving the problem of enterprise combination.

1. THEORETICAL FRAMEWORK

In an attempt to simplify the analysis of production and enterprise combination, we shall assume the following conditions:

1. production is timeless (static); and
2. we have perfect knowledge

The above assumptions appear to avoid the complex and difficult problems of choice and decision making in real life, yet the solutions obtained should uphold whether decisions are made under conditions of certainty or not.

There are three basic decisions that must be coordinated in order to determine the optimum combination of enterprises:

1. factor-product or input-output relationships (the amount of product to produce);
2. factor-factor relationships (the combination of factors to use); and
3. product-product relationships (optimum combination of enterprises).

The first two steps are necessary to arrive at the last decision (optimum combination of enterprises).

Factor-Product or Input-Output Relationships (the amount of product to produce)

In order to focus our attention on the essential principles involved in this decision making, the following assumptions will be made:

1. there is only one variable input;
2. all other inputs necessary for production are considered fixed; and
3. inputs may be combined in various proportions to produce only one commodity (in this case corn).

Let us consider a case, whereby corn is produced. We may represent the production function as:

$$Y = f(X_1 | X_2, X_3, \ldots\ldots X_n)$$

where Y = yield of corn

X_1 = fertilizer

X_2 = labor

X_3 = capital

X_4 = land

X_5 = management

X_6 = weather

$X_7 - X_n$ = other fixed inputs

The interpretation of the function is that corn output depends on the amount of fertilizer applied, when labor, capital, land, management and weather are held constant. This relationship is expressed in Figure 2.

The total output or production is represented as the total physical product (TPP). The marginal physical product (MPP) which is the addition to the total product attributable to the addition of one unit of the variable input to a given amount of the fixed input, may be estimated from the graph. The marginal physical product corresponding to any point on the total physical product curve shown is given by the slope of the tangent to the curve at that point. Another method of determining the MPP is to take the partial derivative of the production function.

There are three stages of production as shown in Figure 2. The first stage represents where

$MPP > APP$ (average physical product) and

E_p (elasticity of production) > 1

The second stage is where

$MPP < APP$ and

$0 \leq E_p \leq 1$,

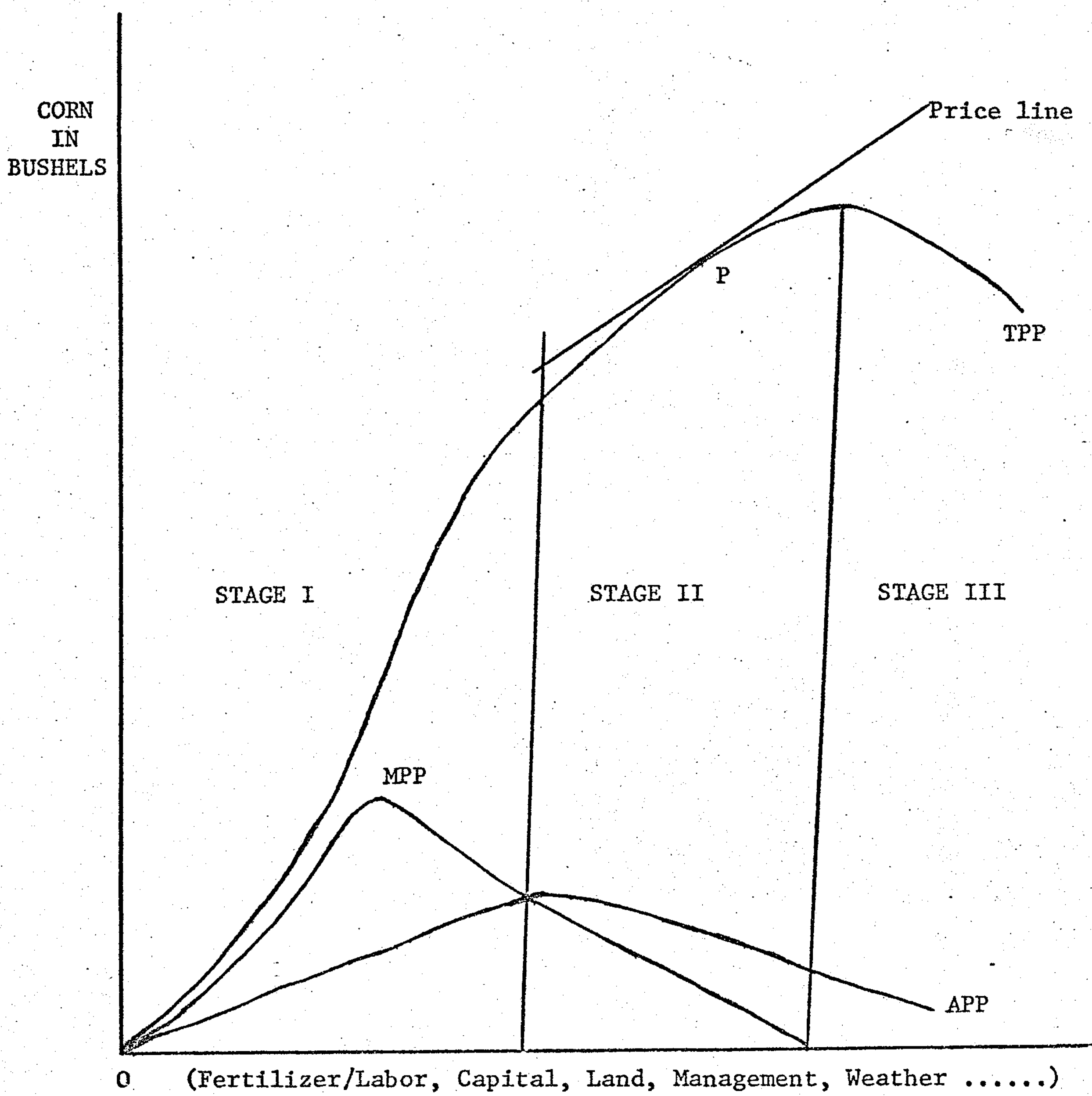
while the third stage represents where

$MPP < 0$, $APP > 0$ and

$E_p < 0$

FIGURE 2

INPUT-OUTPUT RELATIONSHIP



In terms of technical efficiency, we find that stages 1 and 111 are irrational, (because in stage 1 we have increasing average returns to the variable input which in turn are associated with negative marginal returns to the fixed input and stage 111 is the range of negative marginal physical product or declining total product), while the only rational area is stage 11 (where marginal physical product is less than average physical product). Hence a rational producer would never operate in stage 1. Even, if market conditions dictate such a small level of production, then this will be achieved by reducing the amount of fixed input. Stage 111 is completely ruled out because MPP is negative. Production should only occur in stage 11.

A firm practising the relationship so far specified is maximizing its output with a given level of input or put in another way, the firm produces a given level of output with a minimum amount of input. In order to realize economic efficiency the firm has to relate production to the price of corn and the cost of fertilizer. Therefore the operator will continue to produce, if the additional value of corn is greater than the additional cost of fertilizer. When

$MVP^{1}_{corn} = Price_{fertilizer}$ or $\frac{MVP_{corn}}{Price_{fertilizer}} = 1$ then the most profitable amount of corn is produced.

From Figure 2, we may represent the maximum point of production by drawing a price line having the slope of $\frac{\text{price of fertilizer}}{\text{price of corn}}$ to the

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[1]MVP = Marginal Value Product

total physical product curve, where the price line is tangent to the curve, the maximum level of production is obtained and this is represented by point P in Figure 2.

Factor-Factor Relationships (the combination of factors to use)

One of the chief features of production under conditions of variable proportions is that different combinations of inputs can produce a given level of output.

A production function involving two variable factors can be represented as follows:

$$Y = f(X_1, X_2 | X_3, \ldots\ldots X_n)$$

where Y = output

X_1 and X_2 = variable inputs

$X_3 \ldots\ldots X_n$ = fixed inputs

This function states that Y output depends on the variable inputs X_1 and X_2 when $X_3 \ldots\ldots X_n$ are held constant.

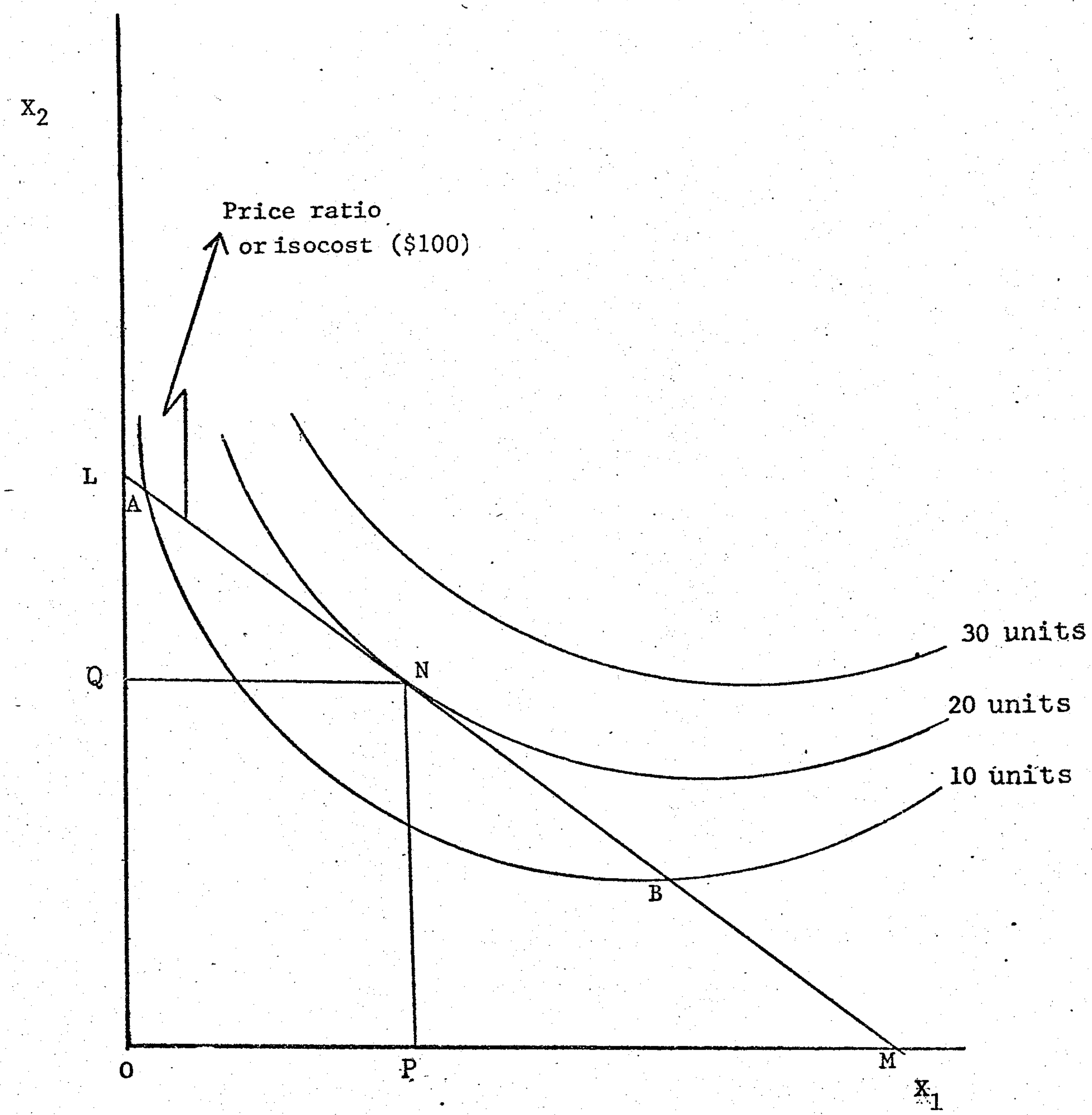
Figure 3 illustrates the production isoquants representing the above factor-factor relationship. An isoquant is a curve in input space representing equal amount of output produced by various combinations of the two variable inputs.

The 20 unit isoquant, for example shows all the possible combinations of X_1 and X_2 that will produce 20 units of Y.

The marginal rate of substitution (MRS) refers to the amount by which one resource or input is decreased as another input is increased by one unit on a given isoquant. It is the slope of the isoquant curve at any particular point. The MRS between two factors (MRS_{x_1} for x_2) is

FIGURE 3

THE FACTOR-FACTOR RELATIONSHIP



the ratio of their marginal physical products (MPP_{x_1}/MPP_{x_2}).

Inputs as well as outputs have specific market prices, therefore for an operator to determine his input combination, he must pay heed to the relative input prices if he is to minimize the cost of producing a given level of output or maximize output for a given level of cost.

Let us assume that line LM in Figure 3 represents a total outlay or a total cost of \$100. LM is called the isocost line, because it represents all the combinations of X_1 and X_2 that have equal total cost. The \$100 may be spent on X_1, then we buy OM units, if spent on X_2 then OL units are purchased or if spent on both, then any combination of the two resources may be purchased. The slope of LM is equal to the (negative) ratio of the price per unit of X_1 to the price per unit of X_2.

The three different isoquants in Figure 3 represent various levels of output i.e. 10, 20 and 30 units, respectively. First consider the 30 unit isoquant, this level of output is not obtainable because the available input combinations limit us to those lying on or below the isocost curve LM.

The producer may operate on points such as A and B (on 10 unit isoquant). However output can be expanded to 20 unit isoquant without incurring any additional cost, except for the selection of an appropriate input combination. Point N, where the 20 unit isoquant is just tangent to the isocost curve is the optimum point, because this is the point where we maximize the output for the given level of cost.

The same solution may be arrived at by differentiating the cost function to obtain the slope of the isocost line. This is then equated to MRS.

$$\frac{MPP_{x_2}}{MPP_{x_1}} = \frac{\text{Price of } x_2}{\text{Price of } x_1} \quad \text{or}$$

$$\frac{MPP_{x_2}}{\text{Price of } x_2} = \frac{MPP_{x_1}}{\text{Price of } x_1}$$

In a more generalised way, the least cost combination for the k th variable is:

$$\frac{MPP_{x_1}}{P_{x_1}} = \frac{MPP_{x_2}}{P_{x_2}} = \ldots\ldots = \frac{MPP_{x_k}}{P_{x_k}}$$

If resources are unlimited (non restricting) then the general procedure, concerning the optimum production is to expand production until:

$$\frac{MVP_{x_1}}{P_{x_1}} = \frac{MVP_{x_2}}{P_{x_2}} = \ldots\ldots = \frac{MVP_{x_k}}{P_{x_k}} = 1$$

In the case of limited resources we produce until:

$$\frac{MVP_{x_1}}{P_{x_1}} = \frac{MVP_{x_2}}{P_{x_2}} = \ldots\ldots = \frac{MVP_{x_k}}{P_{x_k}}$$

that is we continue to produce until $\frac{MVP}{P}$ is equal for all available resources or we stop production before the point is reached where MVP = Price.

Product-Product Relationships (optimum combination of enterprises)

We have so far restricted our discussion to the production of one output, both under the factor-output relationships and factor-factor relationships. It will be necessary at this stage to look at the decision making principle applicable to the production of more than one product.

For the purpose of our discussion, let us assume that two products Corn and Wheat are to be produced, (the same explanation stands for a multi-product firm), with a given set of resources. Each of the two products has its own production function which may be represented thus:

i. $Y_1 = f(X_1, X_2, \ldots\ldots X_n)$

ii. $Y_2 = f(X_1, X_2, \ldots\ldots X_n)$

where Y_1 = yield of corn

and Y_2 = yield of wheat

$X_1 \ldots . X_n$ = given set of resources.

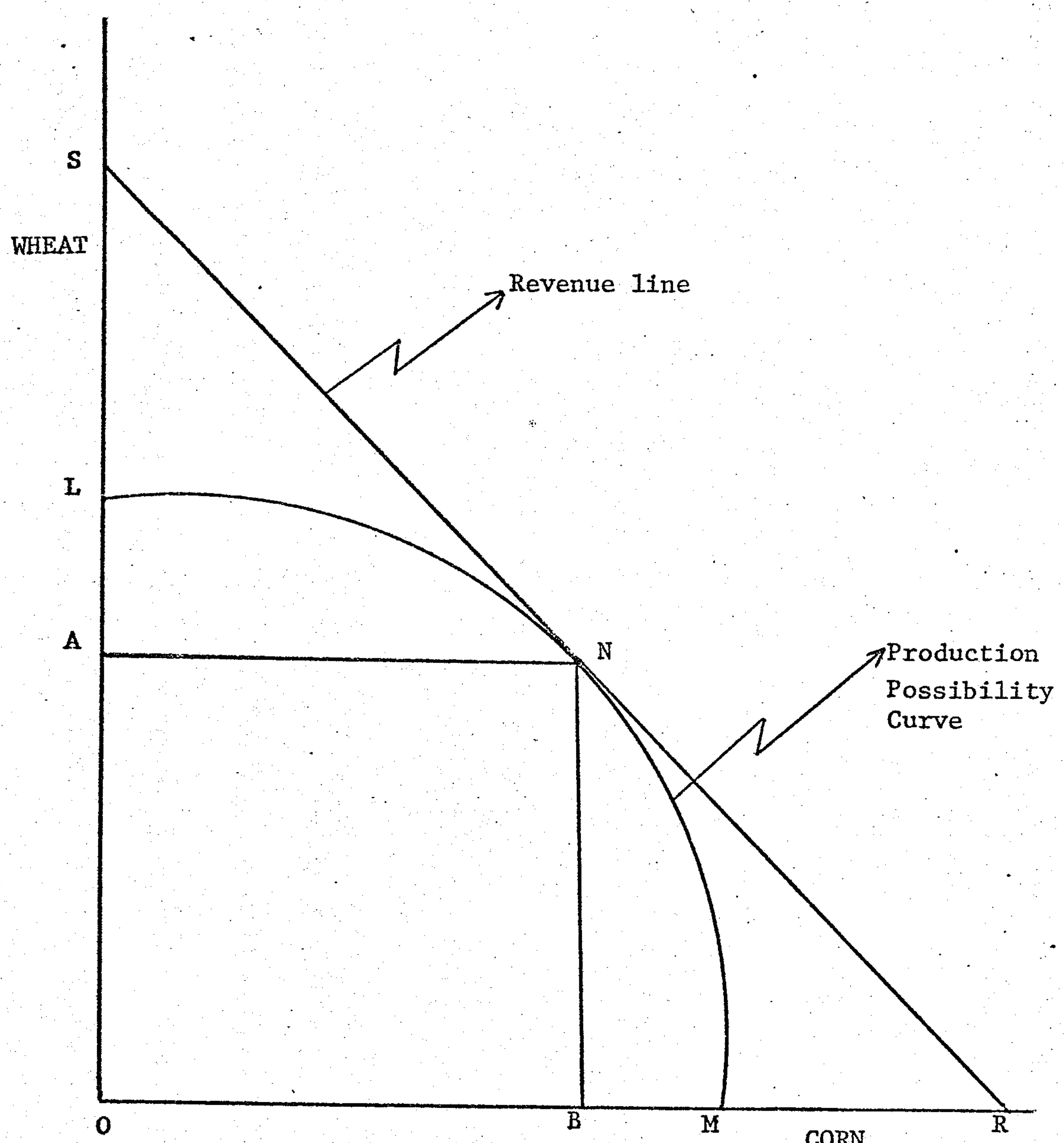
If the market prices of the given set of resources are available, then utilizing the concepts discussed under factor-factor relationships, the inputs will be combined in their least cost combination, that is

$$\frac{MPP_{x_1}}{P_{x_1}} = \frac{MPP_{x_2}}{P_{x_2}} = \ldots\ldots = \frac{MPP_{x_n}}{P_{x_n}}$$

Let us now turn to Figure 4. If all the available resources are used for the production of corn, then OM units of corn are produced, or OL units of wheat are produced if all the resources are devoted to wheat production. The production possibility curve, LM represents the different combinations of corn and wheat that may be produced with the available set of resources. The production possibility curve is also

FIGURE 4

PRODUCT-PRODUCT RELATIONSHIP



referred to as the transformation, iso-resource or iso-cost curve, because it indicates the use of a constant amount of resource at a constant cost for any one planning period.

Two enterprises or activities are generally said to be competitive in the use of resources, if an increase in the output of one can only be achieved through a sacrifice in the output of the other. In effect, we may say that one output is transformed to the other as resources shift backwards and forwards. This may be represented as:

$$Y_1 = f(X_1, X_2, \ldots\ldots X_n, Y_2) \text{ or}$$

$$Y_1 = f(Y_2) \text{ and}$$

$$Y_2 = f(X_1, X_2, \ldots\ldots X_n, Y_1)$$

If the expansion of a competing activity is found desirable (like increasing the production of corn), this will only be possible if we reduce the production of wheat or vice versa.

The core of decision-making in enterprise combination is how to maximize the returns from given resources. In other words, our main concern is to determine an optimum combination of enterprises or activities in order to attain maximum profit, cognizant of the limited resources, which is represented by the production possibility curve or iso-cost curve in Figure 4.

The ratio of prices between the two commodities represents the slope of the iso-revenue curve. In Figure 4, the point of maximum profit, which represents the optimum enterprise combination is shown by point N where the highest iso-revenue line is just tangent to the production possibility curve. This means that with the given set of resources the optimum combination of enterprises is achieved by producing OA units of wheat and OB units of corn. Using the calculus approach, we may further represent the equilibrum condition of enterprise combination as:

$$\frac{MPP_{corn}}{MPP_{wheat}} = \frac{\text{Price of corn}}{\text{Price of wheat}}$$

For a general case, consider a situation where there are Y_k enterprises and the enterprises are combined according to the least cost combination, then

$$\frac{P_{y_1} . MPP(x_1 \ldots x_a)y_1}{P_{x_1 \ldots x_a}} = \frac{P_{y_2} . MPP(x_1 \ldots x_a)y_2}{P_{x_1 \ldots x_a}} = \ldots\ldots = \frac{P_{y_k} . MPP(x_1 \ldots x_a)y_k}{P_{x_1 \ldots x_a}}$$

11. SELECTION OF AN ANALYTICAL TOOL FOR SOLVING THE OPTIMUM COMBINATION OF ENTERPRISES

There are quite a number of analytical tools that can be used to solve the problem of optimum combination of enterprises, but for the purpose of this thesis, we shall only review and evaluate two of them. Before doing so, let us digress a bit to consider the role of management under conditions of uncertainty, which will help us select the most efficient tool for analysing our objective.

The Firm and its Management

The pattern of the society is such that the control of resource allocation for purposes of agricultural production has been vested in the hands of individual farm managers. The fundamental role of management therefore are:

1. to formulate expectations of the conditions

that may likely prevail in the future. This is a necessary pre-requisite before production goals are finalized. The condition must consider future prices, availability of markets, yield of the various crops to be grown and the cost of producing each crop;

2. a plan of production must be formulated on the basis of (1), which is logical and consistent with expectations;

3. the production plan so formulated must be put into action;

and 4. the manager must accept the economic consequences of his plan.

The return to management for correct anticipation of the future and well formed plans are premiums in income.[1]

Our main task is to select an analytical tool that will be effective in solving the second role of management to which priority is attached in this study.

The Farm Budgeting Method

A farm budget is a planning tool which allows us to compare the different crops and livestock that can be produced on the farm and further aids us to arrive at a decision on which of the alternatives is most profitable.

In setting up a budget or plan we set down the prospective acres of each crop and the number of each livestock; we evaluate farming practices and estimate the yield and production; income

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[1]Ibid., pp. 465-467.

> and costs are computed and finally an estimate of net farm income is made. If we make up the budgets for several systems, we predict which one will be most profitable. Every good business man makes up a plan of this sort; he budgets his use of capital and labour.[2]

It is clear that the main objective of budgeting is "to compare alternative plans for the use and combination of farm and non-farm resources for prospective profit"[3] The budget generally considers two or more plans for organizing the farm resources. A comparison of the net returns from each plan is made and the plan that yields the higher net return in view of our objectives is chosen.

However, in practice the budgeting approach soon becomes impracticable under the weight of computations, especially when the alternatives are many. Budgeting generally considers too few alternatives without attempting to exhaust all the possible alternatives. As a result, there are some doubts as to whether the optimum plan arrived at by using this method, actually promotes the attainment of our sets of objectives effectively. Hence the farm budget has been largely restricted to analysing the farm business, where the alternatives are strictly limited.

It should be noted that all the above short comings are not built-in weaknesses in the budgeting technique, but they arise due to short cut methods, that users of the tool often take in an attempt to

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[2]Earl. O. Heady and H. L. Jensen, Farm Management Economics, (Englewood Cliffs, New Jersey: Prentice-Hall, inc., 1961), p. 91.

[3]Faculty of Agriculture and Home Economics, The University of Manitoba, Principles and Practices of Commercial Farming, (Winnipeg: The Public Press Ltd., 1965), p. 357.

side track the fantastic amount of computational work involved when many alternatives have to be considered.

Linear Programming

Linear programming developed as a result of application of a particular mathematical procedure based on linear relationship and linear inequalities to choice problems. The term linear, however is by no means restrictive except that it arises, as a result of:

1. input-output coefficients, which are assumed constant; and
2. resource prices or product prices are also assumed constant, that is, prices do not change with volume of output.

The term inequality follows from the fact that we wish to come up with a plan that

1. does not require using up all the available resources; and
2. assures us that the amount of any activity or commodity produced is not at a negative level.[4]

In actual fact, linear programming is a mathematical method of budgeting, it is frequently used to replace the budgeting method, whenever it allows computation at lower cost and with less time.

The biggest advantage of linear programming is that it employs the use of an electronic computer to compare all possible plans and alternatives in arriving at an optimum solution that effectively satisfies our objective function.[5]

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[4]Earl O. Heady and Wilfred Candler, Linear Programming Methods, (Ames, Iowa: The Iowa State University Press, 1969), p. 5

[5]A linear programming problem may be expressed as:

Linear Programming technique can be applied to any problem that has the following three quantitative components:

1. an objective;
2. alternative methods or processes; and
3. resource or any other restrictions.

In view of the fact that the problems envisaged by this study have the above three quantitative components, that is:

1. maximize net income;
2. different crop production activities; and
3. limited capital, labor, land, et cetera;

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optimize F(x) or $z = \sum_{j=1}^{n} c_j x_j$ ....(1)

Subject to: $\sum_{j=1}^{n} a_{ij} x_j \leq d_i$ for i = 1.........., m.............(2)

$\sum_{j=1}^{n} a_{ij} x_j = d_i$ for i = 1.........., 1.............(3)

$\sum_{j=1}^{n} a_{ij} x_j \geq d_i$ for i = 1.........., k.............(4)

and $x_j \geq 0$ for j = 1.........., n.............(5)

Equation (1) represents the objective function which is either being maximized or minimized; equations (2), (3) and (4) represent m+1+k, structural constraints, each having n number of variables or in a more familiar term, they are the resource restraint i.e., d_i is the amount of resources available, which are used by the activities x_j in a_{ij} amounts per unit output. Equation (5) is included so as to ensure that no activity enters the optimum solution at a negative level.

For a more detailed understanding of Linear Programming procedure, the following references are recommended:

Raymond R. Beneke and Ronald Winterboer, Linear Programming Applications to Farm Planning, (Iowa: The Iowa State University Press, 1971).

Heady and Candler, loc. cit.

also in view of the ease by which the computational problem can be handled, it is felt that linear programming will be most appropriate for the study in question having in mind, however, that linear programming is only a tool and can produce no better result than the quality of the input-output data fed into the program.

Having selected linear programming as the analytical tool for this study, let us now relate it to conventional economic concepts. From the on set, let us remind ourselves that the approach taken by marginal analysis is to solve the problem of optimum combination of enterprises by using a continuous function, whereas linear programming arrives at the same solution making use of a discontinuous function. As an example, in marginal analysis the isoquant manifests a continuously changing slope along the curve (changing MRS), whereas in linear programming the isoquant exhibits straight line segments linking discontinuous points together. The points are various levels of a process where the same level of output are obtained.

The term process is more or less used to connote the same meaning as activity, except that activity is sometimes used to indicate the commodity being produced. A process refers to the method used in in converting resources into a commodity. As a matter of fact, two processes are said to be the same if they use the same resources in the same proportions. For instance, producing corn on a field with 20 pounds

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Chaiho Kim, Introduction to Linear Programming, (New York: Holt, Rinehart and Winston, inc., 1971).

of phosphorous per acre is a different process than producing corn on another field with 50 pounds of phosphorous per acre, despite the fact that all other resources might be homogeneous both in quantity and quality.[6]

Figure 5 shows vector lines being used to illustrate processes in linear programming. Each different point along a vector represents a different level of output produced by the same process at constant returns to scale. The choice indicator in this case like the marginal analysis is the iso-cost line. In order to select the best process for the purpose of production or the best combination of enterprises, the point at which the iso-cost line is just tangent to the isoquant curve represents the optimum point.

Figure 6 represents the production possibility curve. The different iso-resources shown in the diagram indicate the amount of production possible from each of these resources. By superimposing the different iso-resources on one another in the graph, we are able to trace the production possibility frontier facing a firm which has at its command the specified resources, that is, abcd is the production possibility frontier. Production cannot possibly take place at any other points beyond abcd, because either one or more of the resources are unavailable. In order to arrive at the point of optimum combination of enterprises, the price ratio is the determining factor as in marginal analysis. Wherever it is tangent to the production

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[6]Heady and Candler, op. cit., pp. 11-14.

FIGURE 5

FACTOR-FACTOR RELATIONSHIP (discontinuous isoquant)

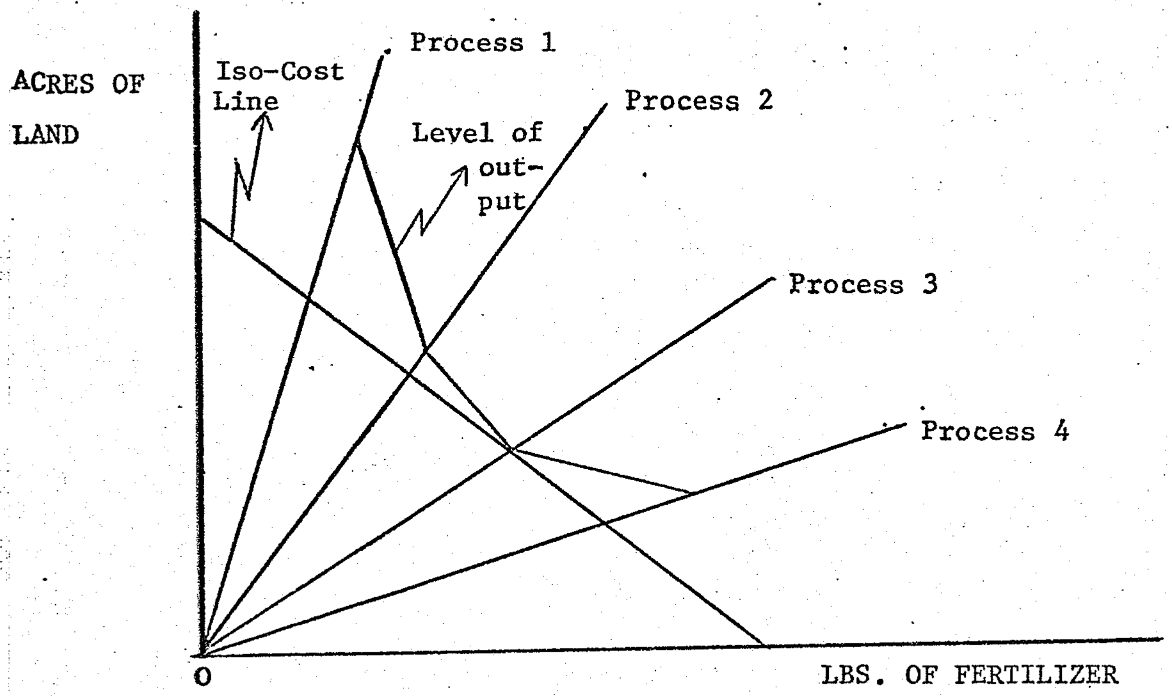
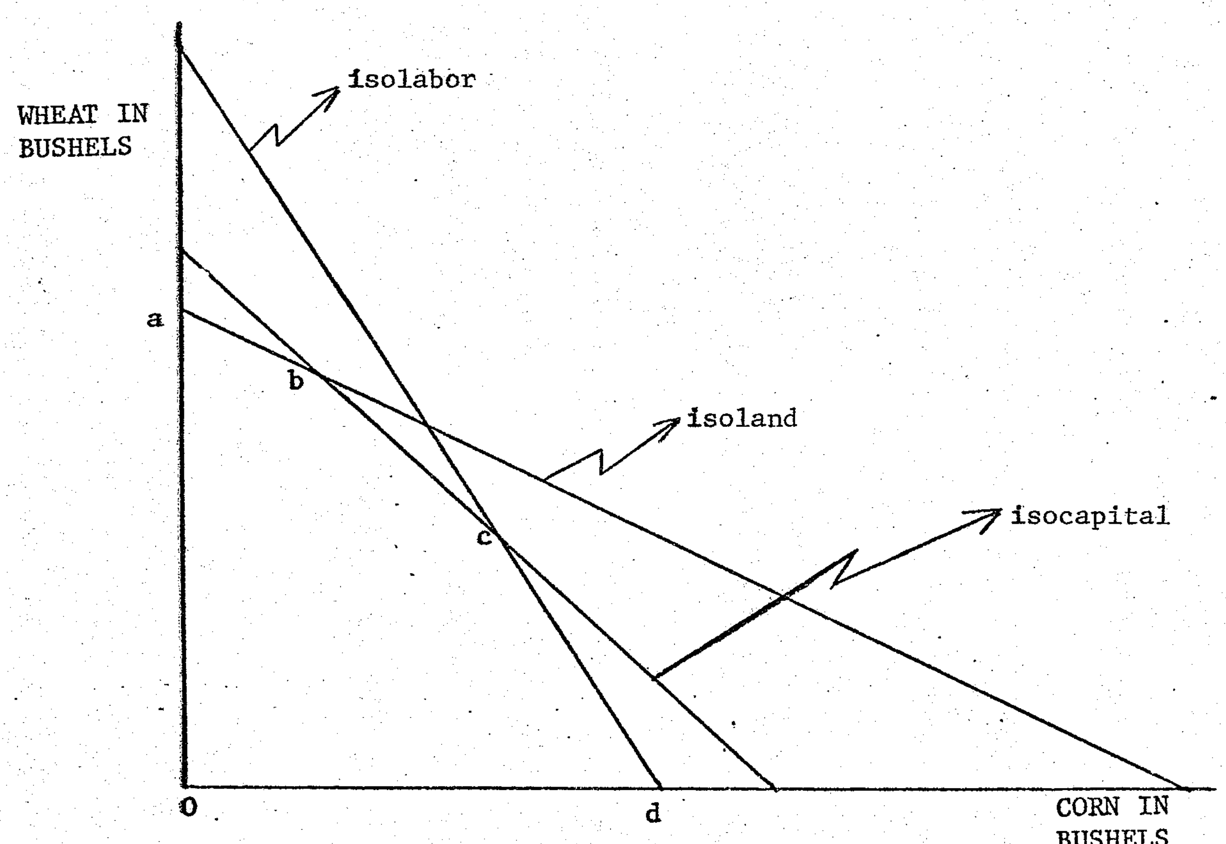


FIGURE 6

PRODUCT-PRODUCT RELATIONSHIP
(discontinuous production possibility curve)



possibility frontier (abcd) we have the optimum combination of enterprises.

In conclusion, the discontinuous function in linear programming approaches the continuous function in marginal analysis as more and more processes are used for production purposes.

CHAPTER IV

THE ANALYTICAL MODEL

The main objective of this study was to develop a program of optimum combination of enterprises for a firm and determine how grain corn competes with the other conventional crops under various specified conditions in the context of profit maximization. Since a direct manipulation of an actual firm was impossible, a mathematical model was built to represent the firm upon which the necessary manipulations were performed. In this chapter we shall first take a look at the characteristics of the case farm, secondly we shall examine the activities and restraints employed in the analytical model to approximate reality with the underlying assumptions and lastly we shall discuss the program situations as they relate to the case model in achieving our sets of objectives.

1. THE CASE FARM

The case farm is a commercial crop production unit located on two different soil associations comprised of 2,880 cultivated acres. The Myrtle clay associate of the Red River soil association constitutes the predominant soil type forming about 70 per cent of the total cultivated acreage followed by the fine sandy loams of the Altona soil association at 20 per cent, while the Osborne clay associate of the Red River association accounts for the remaining ten per cent. The texture of the soil varies from fine sandy loams to clay and this range of light to heavy soil permits a wide selection of crops to be grown.

At present the case farm is solely engaged in the production of crops. Table VI illustrates the kind of crops produced and per acre yields in 1971.

Continuous cropping without summer fallow is an established practice on the case farm and all acres are cropped each year. Recommended fertilizer practices based on soil testing are followed. The only crop produced on contract is sunflowers, the other crops are marketed through the Canadian Wheat Board, the feed industry or the

TABLE VI

KIND OF CROP GROWN AND MARKETABLE
YIELD ON CASE FARM, 1971

Crop	Acreage	Marketable yield per acre
	acres	bushels
Wheat	400	35
Oats	50	80
Barley	545	69
Sunflowers	460	953 pounds
Flaxseed	350	not available
Corn	688	59
Rapeseed	187	30
Rye	200	60
Total acreage	2,880	-

Gimli distillery. Seeding commences in early spring and is usually completed by mid-June. The field operations are fully mechanized and a general line of power and tillage equipment is used for the production of all crops. Special equipment is required for planting, row cultivating and harvesting the corn and sunflower crops.

Intensive mechanization has greatly reduced the labor requirements for each of the crops. Hourly labor requirements on a per acre basis are listed in Table VII. The labor statistics in Table VII include, time spent at tillage, harrowing, seeding, fertilizing, spraying,

TABLE VII

HOURLY LABOR REQUIREMENTS PER ACRE
FOR EACH KIND OF CROP

Crop	Hourly Labor Requirement
	man-hours per acre
Wheat	2.94
Oats	2.94
Barley	2.94
Sunflowers	3.54
Flaxseed	2.94
Corn	3.44
Rapeseed	2.94
Rye	2.94

row crop cultivating (for sunflowers and corn only), harvesting and the operator's supervisory labor. An hourly operational break down of the labor requirements on a per acre basis appears in the Appendix, Table A.1.

11. SPECIFICATION OF THE CASE MODEL

Linear programming was used as the computational tool in this study. The basic linear programming assumptions of additivity, finiteness, linearity, divisibility and single-value expectations were made. It was further assumed that profit maximization was the objective function of the firm.

The basic model used the complement of both owned and hired resources present on the case farm. The initial set of production activities used in the program were based on the current cropping practices on the case farm. By introducing another corn production activity, allowing the cost of corn production to increase due to excess moisture removal from the corn and also varying the different percentage of corn that could be sold to the Gimli distillery, the program generated a pattern of optimum combination of enterprises that formed the basis for recommendations regarding an increase in the corn acreage.

Activities Employed

The case model is a mathematical simulation of the case farm, hence the activities, restrictions, resources and price levels employed in the program were those applicable to the case farm. The activities employed by the program are listed in Table VIII.

TABLE VIII

LIST OF ACTIVITIES EMPLOYED IN THE MODEL

Number	Activity	Unit	c_j value in dollars
1	Corn 1	acre	-46.37
2	Corn 11	acre	-50.58
3	Oats	acre	-22.73
4	Barley	acre	-21.75
5	Rye	acre	-22.38
6	Wheat	acre	-21.98
7	Sunflowers	acre	-27.14
8	Flaxseed	acre	-18.14
9	Rapeseed	acre	-19.44
10	Sell Oats on quota	bushel	0.629
11	Sell Barley on quota	bushel	0.882
12	Sell Rye on quota	bushel	1.042
13	Sell Flaxseed on quota	bushel	2.873
14	Sell Rapeseed on quota	bushel	2.239
15	Sell Wheat on quota	bushel	1.64
16	Sell Wheat for feed	bushel	1.07
17	Sell Oats for feed	bushel	0.52
18	Sell Barley for feed	bushel	0.73
19	Sell Corn for feed	bushel	1.30
20	Sell Sunflowers	pounds	0.052
21	Sell 100% Corn to Gimli	bushel	1.60

TABLE VIII (continued)

Number	Activity	Unit	c_j value in dollars
22	Sell 80% Corn to Gimli	bushel	1.28
23	Sell 50% Corn to Gimli	bushel	0.80
24	Sell 30% Corn to Gimli	bushel	0.48
25	Sell 0% Corn to Gimli	bushel	0.00
26	Rent Owned Land	acres	-9.00
27	Rent Land	acres	-9.00
28	Borrow Personal Savings	dollar	-0.05
29	Borrow Capital	dollar	-0.085
30	Hire Tillage Labor	man-hour	-1.50
31	Hire Harrowing Labor	man-hour	-1.50
32	Hire Seeding Labor	man-hour	-1.50
33	Hire Fertilizer Labor	man-hour	-1.50
34	Hire Spraying Labor	man-hour	-1.50
35	Hire Cultivating Labor	man-hour	-1.50
36	Hire Harvesting Labor	man-hour	-1.50
37	Sell Gimli reject Corn	bushel	1.30
38	Oats quota transfer	bushel	0.00
39	Barley quota transfer	bushel	0.00
40	Rye quota transfer	bushel	0.00
41	Wheat quota transfer	bushel	0.00
42	Flaxseed quota transfer	bushel	0.00
43	Rapeseed quota transfer	bushel	0.00

<u>Crop activities</u>. (1--9). The case model included six conventional crop alternatives, two corn activities and one sunflowers activity. Each of the crops were fertilized at recommended levels. All field operations were mechanized from ploughing through harvesting. The conventional crops were marketed through the Canadian Wheat Board or to the feed industry; sunflowers were grown on contract while corn was either sold to the Gimli distillery or to the feed industry.

The different crop activities employed by the model reflected the actual practice followed on the case farm except for Corn activity 11 which served as an alternative process for producing corn, this assumed fertilizer requirements to achieve a target yield which were estimated by the Provincial Soil Testing Laboratory at the University of Manitoba.

The cost of production of all the different crop activities carried a negative c_j value in the program. They were extracted from the available records on the case farm and consisted of both variable and fixed costs (depreciation on buildings, machinery and equipment at a nine per cent rate, opportunity cost on investment on buildings, machinery and equipment at eight per cent and land tax of $2 per acre). Corn production 11 carried an additional variable cost above that of corn production 1 due to the additional fertilizer usage and the cost of drying the extra 11.76 bushels yield per acre. The break down of the cost of production for each of the crop activities is found in the Appendix, Table A.2.

Expected yields for the various crops are shown in Table IX. A Table showing how the average yields were derived is found in the Appendix, Table A.3.

TABLE IX

EXPECTED YIELDS OF CROP ACTIVITIES

Crop	Expected Marketable Yield
	bushels
Corn 1	58
Corn 11	70*
Oats	70
Barley	55
Rye	45
Wheat	28
Sunflowers	953 pounds
Flaxseed	13
Rapeseed	23

Source:

Yields are averages for the case farm over the period 1968 through 1971. (See Appendix, Table A.3)

*Estimated target yield supplied by Provincial Soil Testing Laboratory.

Selling activities. (10--25 and 37). For the purpose of this study it was assumed that all crops produced could be sold, (an exception is discussed later). All c_j values attached to the selling activities carried a positive sign. The selling activities as used by the model were classified under five main headings:

1. Quota selling activities: (10--15). All the conventional

grains could be marketed through the Canadian Wheat Board on quota. (The quota restriction will be discussed under the set of restraints employed by the model). The c_j values used were averages calculated over a period of ten years 1960-1970 from the Manitoba Agriculture 1970 Year Book;

2. Feed selling activities: (17--19). Wheat, oats, barley and corn had an alternative marketing outlet through the feed industry. The c_j values used were collected from the feed industry over a period of 1969 through 1971 and the average was taken;

3. Contract selling activity: (20). Sunflowers were the only crop sold on a contract basis. The c_j value was obtained as in 1;

4. Gimli selling activities: (21--25). The Gimli distillery requires corn as an input factor in the distillation of grain alcohol, hence Gimli pays a premium price for good quality grain corn. For the purpose of a meaningful analysis, it was assumed that various amounts of corn could be sold to Gimli varying from 100 per cent of the crop to zero per cent. The c_j value of \$1.60 was the average price paid by Gimli over the period 1969-1971. For the 100 per cent sale to Gimli the c_j value was \$1.60, but the other percentages showed various lesser amounts of c_j values. For example, let us consider the case where 80 per cent of the crop is accepted at Gimli. Total revenue may be calculated in either of two ways: (i) take 80 per cent of the c_j value (\$1.28) and allow 100 per cent sale as specified in our program or, (ii)

allow a c_j value of \$1.60 and sell 80 per cent of production.

5. Gimli reject corn selling activity: (37). In view of our assumptions that everything produced must be sold, corn rejected by Gimli was marketed through the feed industry at a c_j value of \$1.30 per bushel.

Land activities. (26, 27). For the purpose of this study an opportunity cost of \$11 per acre was charged for the operator's owned land. The opportunity cost is equivalent to the cost of renting land in the area. A Rent Owned Land activity was designed to achieve this objective. The c_j value was a negative \$9, the other \$2 required to make up the \$11 rent was included in the fixed cost of each of the different crops produced as land tax. The same result could be achieved by decreasing the cost of producing each crop activity by \$2 and increasing the c_j value on Rent Owned Land to \$11.

Another activity Rent Land was included in the program to allow for renting more land under the same assumptions described above.

Operating capital activities. (28, 29). The program included an activity entitled borrow personal savings in order to allow the use of the operator's own capital in defraying some of the operating expenses. This activity was charged with an interest rate of five per cent which represented the average short term opportunity cost of using the capital in a non-farm use. In this case it was assumed that the capital must be a working capital so it cannot earn an opportunity cost higher than a personal savings account in a commercial bank. The personal capital was further augmented by a borrow capital activity.

This allowed the farm operator access to credit facilities up to a specified limit with an interest rate of eight and one half per cent.

Hire labor activities. (30--36). Most of the labor used was hired and seven activities provided for the purchase of labor services on an operational basis (Hire Tillage Labor ------ Hire Harvesting Labor). The operator functioned in a dual capacity both as a supervisor and also as a worker. The operator's labor was not charged any cost. The different labor purchasing activities carried a negative c_j value of $1.50 which was the hourly wage rate prevailing on the case farm in 1971.

Transfer activities. (38---43). These were quota transfer activities and as such carried no c_j values. They were included in the program so as to be able to derive an indication on how best to allocate Canadian Wheat Board delivery quotas so as to derive a maximum benefit (further explanation will come under program restraints).

Restraints Utilized in the Model

The levels at which the above described activities may enter the optimum solution are limited by the type of restraints imposed in the program. These were:

1. resource restraints - which were quantitative limits on the availability of resources;
2. institutional restraints - which were in the form of quota purchases of grain crops;
3. subjective restraints - which expressed the desire of the farm operator to hedge against risks and uncertainties by diversification.

The different types of restraints used by the case model are listed in Table X.

TABLE X

LIST OF RESTRAINTS UTILIZED IN THE MODEL

Number	Title	Unit	restraint level (b_i)
1	Owned land	acre	1,840
2	Land	acre	0
3	Rent land limit	acre	1,040
4	Personal savings	dollar	54,530
5	Operating capital	dollar	0
6	Borrowing limit on capital	dollar	172,782
7	Total labor supply	man-hour	0
8	Tillage labor supply	man-hour	0
9	Harrow labor supply	man-hour	228
10	Seeding labor supply	man-hour	234
11	Fertilizing labor supply	man-hour	0
12	Spraying labor supply	man-hour	114
13	Row Crop Cultivating labor supply	man-hour	312
14	Harvest labor supply	man-hour	282
15	Operator's Supervising	man-hour	351
16	Maximum Harrow labor supply	man-hour	772
17	Maximum seeding labor supply	man-hour	1,560
18	Maximum corn seeding labor supply	man-hour	264

TABLE X (continued)

Number	Title	Unit	restraint level (b_i)
19	Corn supply	bushel	0
20	Oats supply	bushel	0
21	Barley supply	bushel	0
22	Rye supply	bushel	0
23	Wheat supply	bushel	0
24	Sunflowers supply	pounds	0
25	Flaxseed supply	bushel	0
26	Rapeseed supply	bushel	0
27	Gimli reject corn supply	bushel	0
28	Assignable acres	bushel	0
29	Oats quota supply	bushel	0
30	Barley quota supply	bushel	0
31	Rye quota supply	bushel	0
32	Wheat quota supply	bushel	0
33	Flaxseed quota supply	bushel	0
34	Rapeseed quota supply	bushel	0
35	Corn production maximum limit	acres	1,000
36	Oats production maximum limit	acres	50
37	Barley production maximum limit	acres	1,000
38	Rye production maximum limit	acres	200
39	Wheat production maximum limit	acres	1,000

TABLE X (continued)

Number	Title	Unit	restraints level (b_i)
40	Sunflowers production maximum limit	acres	500
41	Flaxseed production maximum limit	acres	1,000
42	Rapeseed production maximum limit	acres	160
43	Corn production minimum limit	acres	200
44	Barley production minimum limit	acres	200
45	Wheat production minimum limit	acres	200
46	Sunflowers production minimum limit	acres	100
47	Flaxseed production minimum limit	acres	200

Land restraints. (1---3). The case model included three land restraints. The first, owned land represented the limit of the land owned by the farm operator (1840 acres). The second allowed for either owned land or rented land to be used by the program for production purposes. The third land restriction placed a ceiling on the amount of land that could be rented through rental activities and the limit of 1040 acres reflected the subjective restraint placed on rented land as expressed by the manager.

Capital restraints. (4---6). Three restraints were used to limit the amount and utilization of operating capital. The first restraint allowed the program to use operator's personal savings up to a limit of $54,530. The second which was the operating capital restraint was fixed at a zero level and actually supplied the operating capital for the program which was drawn from either personal savings or borrowed capital. The third and the last capital restraint was the borrowing limit on capital. To arrive at this limit, it was assumed that the farmer could borrow up to 40 per cent of his equity in the farm business.

Labor restraints. (7---18). The program utilized seven restraints to limit the labor supply for each of the different operations on the fields from which the different crop activities might draw. The total labor supply restraint put at zero level, only performed a counting role - that is - it allowed the programmer to keep track of the total labor used by the program. Three more restraints placed maximum limits on the supply of labor for harrowing, seeding and corn planting. The latter restraints were necessary because the operations were carried out on the case farm when the available labor supply was fixed. The assumption used in the calculation of available man-hours for any particular operation was 26 working days in a month and 12 man-hours per working day.

Crop supply restraints. (19---27). Nine restraints represented the crop supply restraints. These restraints were put at zero level but whenever an acre of a specific crop was cultivated, the program added the specified yield per acre of that crop to the relevant crop supply restraint. The selling activities then drew a unit at a time from the crop supply restraint. The Gimli corn reject supply restraint was designed to take care of all the rejects from the Gimli market from which the activity, sell Gimli reject could draw a unit at a time.

Quota restraints. (28---34). Six restraints were used in the program to represent institutional restraints on marketing conventional grain crops. The quota restraints limited the amount of each conventional grain crop that might be delivered to the elevator. The basic specified acreage quota in this exercise assumed a 12 bushel quota for oats, 40 bushel quota for barley, 30 bushel quota for rye, 8 bushel quota for wheat, 15 bushel quota for flaxseed and a 12 bushel quota for rapeseed.[1] The assignable acres restraint was included so as to allow the farm operator to assign acreage of both quota and non-quota crops for Canadian Wheat Board deliveries. In order to maximize the quota delivery, acreage transfer activities between quota and non-quota crops were employed in the program.

Crop production maximum restraints. (35---42). Eight restraints provided the quantitative maximum production limit placed on each of the crop activity. These reflected the subjective restraint expressed by the manager.

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[1]1971 Canadian Wheat Board quotas were used on the assumption that they represented current trends in grain deliveries.

Crop production minimum restraints. (43---47). The program utilized five minimum crop production restraints to express the desire of management to hedge against possible weather hazards and uncertainties. These restraints ensured that at least the minimum specified acreage was forced into the program to satisfy the problem of diversification, despite the fact that it might not necessarily be in the overall interest of profit maximization.

Summary Description of the Case Model

The case model was a mathematical simulation of the production and marketing alternatives open to the case farm and the restraints (resource, subjective and institutional) which limited the choice of these alternatives. The model was specified as a linear programming problem having a matrix with 47 rows and 43 columns. The objective function of the model was to maximize net income. Nine cropping activities and thirteen selling activities represented both the production and marketing alternatives open to the case farm business. The remaining activities provided for acquisition of additional variable and fixed resources as well as for quota transfers.

The resource requirements which formed the greater part of the input-output coefficients for the program were calculated on a per acre basis for crop activities, while the c_j coefficients for the selling activities were unit sale prices. The initial simplex tableau is shown in the Appendix, Figure A.1.

Description of the Program Situations as related to the Case Model

The set of objectives as related to the case model were enumerated in Chapter I and are as follows:

1. to determine the optimum combination of the various crops grown with the available resources on the case farm in 1971, with a view to determine how best to organize the farm business and at the same time examine how grain corn competes with other crops;

2. to observe how an increase in the cost of drying corn adds to corn production costs and affects the optimum solution in 1;

3. to determine the effect of varying the quantity of grain corn marketed through Gimli on the optima obtained in 1 and 2, thereby determining how grain corn competes with the other crops when price and quantity are varied;

4. to examine the optimum solution in 2 when a portion of the grain corn crop fails to meet the quality standards set by the Gimli plant, while at the same time the feed industry does not provide an alternate market; and

5. to perform a sensitivity analysis on 1.

The set of objectives were achieved by allowing the case model to generate several solutions. The computer runs with regard to the case model are summarized below:

Program 1. In order to attain the first objective the program restraints were set at levels that utilized both owned and hired resources as obtained on the case farm in 1971. Both maximum and minimum restraints on crop production were included in the computer runs. Two computer runs were used:

i. to simulate the cropping practice on the case farm, all the cropping activities including the corn production activity (corn 1) were based on the costs and average yields experienced by the case farm in 1971;

ii. another corn production process (corn 11) was included in run (i). This was based on target yield predictions, hence the costs as well as yields were calculated on that basis. (See Appendix, Table A.2)

Program 2. Objective 2. This objective was attained by using run (i) in program (1), the difference being that while run (i) in program (1) only contained the cost of drying grain corn from 25 per cent to 13 per cent, program 2 incorporated the increased cost of drying grain corn from 35 per cent to 13 per cent, (above 35 per cent moisture grain corn cannot be harvested).

Program 3. Objective 3. 14 computer runs were used to examine this objective. The first set of the eight runs were modified versions of the Programs (1) (i) and (ii) and are identified as Program 3.1; A and B. The modified program placed a restriction on the amount of corn that met the specification of the Gimli distillery. The restrictions imposed for different proportion of the crop were 80 per cent, 50 per cent, 30 per cent and zero per cent respectively. The corn that failed to meet the Gimli market requirements were called Gimli reject and were sold for feed at a lower price.

The next series of four runs (called Program 3.2) were based on Program 2, again the same set of market restrictions as the ones described above were used.

The last set of two runs (called modified Program 3.2) introduced corn activity 11 into the Program. Production costs were increased to allow for drying from 35 per cent moisture content to 13 per cent. The modified Program 3.2 was then run for a restricted sale to the Gimli distillery at 80 per cent and zero per cent of the crop. These runs are represented diagramatically in Figure 7 below.

FIGURE 7

COMPUTER RUNS USED TO ANALYSE MARKETING OF VARIOUS QUANTITIES OF CORN THROUGH GIMLI

Percentage Gimli's sale restriction on corn	run	PROGRAM 3.1 A Corn 1 (as practiced on case farm)	PROGRAM 3.1 B Corn 1 and 11 (Target Yield corn included)	PROGRAM 3.2 Corn 1 (increase cost of drying)	MODIFIED PROGRAM 3.2 Corn 1 and 11 (increase cost of drying)
80	i	x	x	x	x
50	ii	x	x	x	
30	iii	x	x	x	
0	iv	x	x	x	x

Program 4. Objective 4. Three runs were made use of in an attempt to attain this objective. Program 2 was the basic program modified for this purpose. The modification being the inclusion of marketing restraints on the sale of grain corn to Gimli (80 per cent, 50 per cent and 30 per cent of the crop respectively) and assigning a c_j value of zero which assumed no market opportunities exist for feed corn.

Program 5. Objective 5. Four different types of sensitivity analysis were performed. In each case Program (1) (i) served as the basis for further modification, because it was found to be more realistic in terms of costs and yields being the actual production practice on the case farm. The four runs that made up the sensitivity analysis are as follows:

i. no minimum restraint was placed on the level of corn production. The c_j value of the activity sell corn to Gimli, was varied by ten cents at a time until a total of 80 cents was subtracted while the c_j value of the activities, sell corn for feed and sell Gimli reject corn were kept constant at the original value of \$1.30. Only 80 per cent of the total corn production was allowed to be sold to Gimli;

ii. the minimum restraint on the level of corn production was removed. The c_j value of the activity, sell corn to Gimli, was kept constant at \$1.60 while the c_j value of the activity, sell Gimli reject corn was varied by ten cents at a time until a total of 80 cents was deducted. In this case only 50 per cent of the total corn production was assumed acceptable to the Gimli market;

iii. the minimum restraint on the level of corn production was again removed. Both c_j values of the activities, sell corn to Gimli and sell Gimli reject corn were varied simultaneously by ten cents and eight cents, respectively. This continued until the c_j value of the activity, sell corn to Gimli was reduced to 60 cents and that of sell Gimli corn reject to 50 cents. An 80 per cent restriction level was placed on the quantity of grain corn that could be sold to the Gimli distillery;

iv. all the minimum restraints on the level of crop production were lifted. Current estimated c_j values were placed on all crops marketed through the Canadian Wheat Board on a quota basis, as well as the sell sunflowers activity. The c_j value of the sell corn activities, however were kept constant at the original c_j value. The activities with new c_j values are listed in Table XI below.

TABLE XI

LIST OF ACTIVITIES WITH ALTERNATIVE PRICES

Number	Activity	Unit	c_j value in dollars
10	Sell oats on quota	bushel	0.75
11	Sell barley on quota	bushel	1.00
12	Sell rye on quota	bushel	1.30
13	Sell flaxseed on quota	bushel	4.00
14	Sell rapeseed on quota	bushel	3.50
15	Sell wheat on quota	bushel	2.00
20	Sell sunflowers	pounds	0.07

CHAPTER V

RESULTS AND INTERPRETATION OF COMPUTATIONS

This Chapter discusses the results of the computer output of the programs outlined in Chapter IV. The procedure will be to make use of tables and narration to describe and interpret the solutions generated by the case model. Perhaps before presenting the results, a more meaningful interpretation will be achieved, if we first take a brief look at the type of information generated by the computer for a linear programming problem.

1. INFORMATION GENERATED BY A LINEAR PROGRAMMING SOLUTION

The computer solution to a linear programming problem in the form of a printed output[1] consists of the optimum plan (final plan) as well as auxillary information which can be used to interpret the results. The objective of a linear programming exercise is to find the value of the plan resulting from the optimization of the model presented. This value is found in Section 1 of the printed output under the cost row of the column labelled ACTIVITY.[2] The remaining entries in this column indicate how much of the original value of the resources were used in the

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[1]Readers are referred to Billy G. Freeman and Curtis F. Lard, A User's Guide to Linear Programming and the IBM MPS-360 Computer Routine, (Texas: Departmental Technical Report 70-2, 1970), pp. 14-19, for an example of computer solution to a linear programming problem.

[2]The particular format described here is peculiar to IBM MPS-360 Computer Routine. (See ibid).

production process. The optimum plan or final plan of the program is provided in Section 2 of the output. A list of the levels of activities that enter the solution is represented carrying the units in which the activity was defined in the model constructed.

The remaining information collected from the computer printout includes the shadow prices, unused resources and reduced costs. The shadow prices for the disposal activities are printed under the column labelled DUAL ACTIVITY and are marginal values specifying the change in the value of the program which would result due to an increase or a decrease of one unit of the limiting resource in the original level column entry. For instance, let us consider an example from our case model. In one of the programs the maximum corn seeding labor data appeared as follows in the solution:

Shadow price	74.19
Lower limit	-76.26
Upper limit	45

The interpretation of the above is that the value of the objective function could be increased by the amount of \$74.19 for each additional man-hour of corn seeding labor added to the maximum corn seeding labor supply up to a maximum of 45 additional man-hours provided all other restraints and price levels are kept constant. Conversely a loss of \$74.19 per man-hour would be incurred if the maximum seeding labor restraint level were to be decreased. In other words, we can say that the shadow price of \$74.19 is only applicable over the range of (264 - 76.26) to (264 + 45) man-hours.

The reduced cost column shows the income penalties attached to forcing one unit of the activity into the solution. Let us continue to use our former example, the following printout appeared against sell wheat for feed activity:

Sell wheat for feed	Basic solution	0
	reduced cost column	.44

The interpretation is that sell wheat for feed activity is not in the basic solution (that is, its value is zero). Under the reduced cost column we find that forcing one unit of sell wheat for feed activity into the solution would decrease the value of the program by 44 cents.

11. OPTIMUM PLAN FOR THE CASE FARM

The optima generated by the case model is tabulated in Table XII. The Table presents the results for the two runs used in Program 1 to attain the first objective and the format used was to present the optima solution in the form of; value of the objective function, optimum production plan, resources used, unused resources and shadow prices of the limiting resources.

In Program 1 run (i) the optimum value of the objective function was $48,521.11 which represents the net return to management and operator's labor. The program had adjusted for the fixed costs associated with every crop produced as well as the opportunity cost for using the factors of production in a non-farm use.

The optimum production plan that maximized the net income of the case farm was to plant 854 acres of corn, 1000 acres of barley, 200 acres of rye, 206 acres of wheat, 253 acres of sunflowers, 200 acres of flaxseed and 160 acres of rapeseed. Before discussing

TABLE XII

SOLUTION DATA: PROGRAM 1

	Unit	Results Run: i	ii
Optimum Production Plan			
Corn I	acres	854.37	--
Corn II	acres	--	854.37
Barley	acres	1,000.00	1,000.00
Rye	acres	200.00	200.00
Wheat	acres	205.98	205.98
Sunflowers	acres	253.21	253.21
Flaxseed	acres	200.00	200.00
Rapeseed	acres	160.00	160.00
Total Acreage	acres	2,873.56	2,873.56
Resources Used			
Owned Land	acres	1,833.56	1,833.56
Rented Land	acres	1,040.00	1,040.00
Personal Savings	dollars	54,130.00	54,130.00
Borrowed Capital	dollars	29,851.15	33,448.04
Total Labour	hours	16,550.00	16,550.00
Tillage Labour	hours	1,788.22	1,788.22
Fertilizer Labour	hours	683.91	683.91
Spraying Labour	hours	647.48	647.48
Row Crop Cultivating Labour	hours	809.64	809.64
Harvesting Labour	hours	3,484.21	3,484.21
Supervision Labour	hours	336.21	336.21
Maximum Harrowing Labour	hours	772.00	772.00
Maximum Seeding Labour	hours	1,322.88	1,322.88
Maximum Corn Seeding Labour	hours	264.00	264.00
Resources Left Unused			
Owned Land	acres	6.44	6.44
Supervision Labour	hours	14.79	14.79
Maximum Seeding Labour	hours	237.12	237.12
Shadow Prices of Limiting Resources			
Personal Savings	$/dollar	0.04	0.04
Harrowing Labour	$/hour	20.04	20.04
Corn Seeding Labour	$/hour	74.19	120.30
Optimum Value of the Objective Function	dollars	48,521.11	60,694.28

the implications of this pattern of production, we should recall that in order to diversify production the manager had expressed a desire to produce at least a minimum acreage of certain crops which led to the minimum restraint used in the case model. Also, the maximum restraint used in the program reflected a similar subjective restraint.[3] The quantity of each crop produced over and above the minimum restraint were as follows: 654 acres of corn, 800 acres of barley, 200 acres of rye, six acres of wheat, 153 acres of sunflowers, 160 acres of rapeseed. Three of the crops, barley, rapeseed and rye were produced at the maximum level allowed by the program. In actual fact three crops were very important to the cropping program of the case farm as presented in Table XII, they were corn, barley and rapeseed.

If we use the partial budgeting approach under the assumption that there are no quota restraints on barley and rapeseed and the total quantity produced of the two crops could be sold to the Wheat Board, then we find that a net profit of $8.90 per acre and $17.97 per acre were made on barley and rapeseed respectively. Using the same procedure, corn returned a net profit of $26.63 per acre, if the total quantity of corn produced per acre could be sold to the Gimli distillery. For this particular program grain corn was found to contribute a net income of $22,768.96 out of the total net income of $48,521.11 realized by the program which was about half of the profit generated by Program 1 run (i). From the above discussion, we find that grain corn can compete very well

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[3] See discussion re crop restraints pp. 62-63.

with the other crops and contributes significantly to attainting the objective function of this study which was to maximize the farmer's net income.

The resources used in achieving this optimum production plan are shown in Table XII, we note that owned land was not completely used up by the program before land was rented. In the program, we specified the opportunity cost of owned land as equivalent to the cost of renting land in the area. This meant that no matter which type of land was utilized by the program, the cost to the program remained the same. The limiting resource affecting an increase in corn acreage was apparently the labor supply available at planting time. We find that the addition of one unit of corn seeding labor to the program would increase the value of our objective function by $74.19. Also, the limiting factor on the production of the other crops, that are grown in order to attain the objective function was the labor supply associated with the seeding period. If the case farm was to find it necessary to expand the farm business, this would not be possible unless it could provide for additional labor during the critical planting period.

The results generated by Program 1 run (ii) presented in Table XII were almost similar to that of run (i). In run (ii) we included corn activity 11 as an alternative corn production process. The optimum plan of run (ii) included the production of 854 acres of corn 11 and no acreage of corn 1, otherwise the optimum production plan remained the same as in run (i). The net income generated by run (ii) was $60,694.28 and the shadow price on corn seeding labor was $120.30. This suggests that target yield projections should be considered as a profitable practice in the production of corn. Apart from the points raised above, the same interpretation as in Program 1 run (i) is found applicable to run (ii).

Program Solution with Increased Cost of Producing Grain Corn - Program 2

Table XIII summarizes the optimum plan generated by Program 2. This Program included an increase in the cost of producing grain corn due to the removal of excess moisture. In other words, if weather dictated an early harvesting of grain corn, then we would be interested in knowing how such a practice would affect the optimum solution obtained in Program 1 run (i). Both the minimum and maximum restraints on the level of crop production activities were left intact in the Program.

The optimum value of the objective function was $46,149.87. Despite the increase in the cost of producing grain corn, the Program found corn a profitable enterprise and 854 acres were planted which was the same as in Program 1 run (i). The major difference between Program 11 and Program 1 run (i) was that the net income generated by Program 11 was slightly less than that of Program 1 run (i). Also the shadow price attached to the corn seeding labor in Program 11 which was $65.21 was lower than the shadow price of the same resource in Program 1 run (i).

It has been shown that an increase in the cost of producing grain corn due to excess moisture drying from 35 per cent to 13 per cent, instead of the usual practice of 25 per cent to 13 per cent does not necessarily affect the competitive position of grain corn with other conventional crops since the optimum production plan of Program 2 remained the same as in Program 1 run (i). The optimum value of the

TABLE XIII

SOLUTION DATA: PROGRAM 2

	Unit	Results
Optimum Production Plan		
Corn I	acres	854.37
Barley	acres	1,000.00
Rye	acres	200.00
Wheat	acres	205.98
Sunflowers	acres	253.21
Flaxseed	acres	200.00
Rapeseed	acres	160.00
Total Acreage	acres	2,873.56
Resources Used		
Owned Land	acres	1,833.56
Rented Land	acres	1,040.00
Personal Savings	dollars	54,130.00
Borrowed Capital	dollars	32,036.62
Total Labour	hours	16,550.00
Tillage Labour	hours	1,788.22
Fertilizer Labour	hours	683.91
Spraying Labour	hours	647.48
Row Crop Cultivating Labour	hours	809.64
Harvesting Labour	hours	3,484.21
Supervision Labour	hours	336.21
Maximum Harrowing Labour	hours	772.00
Maximum Seeding Labour	hours	1,322.88
Maximum Corn Seeding Labour	hours	264.00
Unused Resources		
Owned Land	acres	6.44
Supervision Labour	hours	14.79
Maximum Seeding Labour	hours	237.12
Shadow Prices of Limiting Resources		
Personal Savings	$/dollar	0.04
Harrowing Labour	$/hour	20.04
Corn Seeding Labour	$/hour	65.21
Optimum Value of the Objective Function	dollars	46,149.87

Program was reduced by $1,371.24.

Program Solutions with Various Restricted Quantities of Grain Corn Marketed Through Gimli - Program 3

In the last two Programs examined and discussed, the quantity of grain corn that could be sold to the Gimli distillery was not restricted because we assumed that everything produced could meet the distillery specifications. However, we shall now relax this assumption and vary the quantity of grain corn that could be marketed through Gimli ranging from 80 per cent to zero per cent. As discussed in Chapter IV, there was another selling activity that provided for the sale of grain corn rejects from the Gimli distillery as livestock-feed.

The results obtained by Program 3 are tabulated in Table XIV. In view of the fact that the optimum production plan did not change from those generated by Program 1 runs (i) and (ii) and Program 2, unnecessary repetition was therefore avoided so Table XIV only presents the optimum value of the objective function as well as the shadow prices attached to corn seeding labor.

Program 3.1A runs (i) (ii) (iii) and (iv) showed that the net income generated by restricting the percentage grain corn sold to Gimli in all the four different runs were lower than the one generated when there was no restriction on sale, that is, $48,521.11. The net income also decreased as the percentage restriction decreased, that is, 80 per cent restriction generated a better net income than 50 per cent and so on. If we use the partial budgeting approach to examine the zero per cent restricted sale to Gimli whereby all grain corn produced

TABLE XIV

SOLUTION DATA: PROGRAM 3

Percentage Gimili's Sale Restriction on Corn	Run	OPTIMUM VALUE OF THE OBJECTIVE FUNCTION: Program 3.1* A	Program 3.1* B	Program 3.2	Modified Program 3.2	SHADOW PRICES OF CORN SEEDING LABOUR: Program 3.1* A	Program 3.1* B	Program 3.2	Modified Program 3.2
		$	$	$	$	$/hour	$/hour	$/hour	$/hour
80	i	45,535.60	57,105.93	43,164.36	54,572.47	62.88	106.70	53.90	97.11
50	ii	41,057.34	51,723.41	38,686.10	--**	45.92	86.32	36.94	--**
30	iii	38,071.83	48,135.06	35,700.59	--**	34.61	72.73	25.63	--**
0	iv	33,593.57	42,752.54	31,222.33	40,219.07	17.65	52.34	8.67	42.74

*Program 3.1A included only corn activity 1 while Program 3.1B included both corn activities 1 and 11.

**No programs were run, hence no result.

was to be sold for feed at a price of $1.30, the net return per acre was $9.15. This compares fairly well with the $8.90 per acre return on barley discussed under Program 1 run (i).

Program 3.1B runs (i) (ii) (iii) and (iv) differed from Program 3.1A because corn activity 11 was included as an alternative corn process to corn activity 1. The net income realized in each of the runs in Program 3.1B was comparatively higher than the equivalent runs in Program 3.1A. This again suggests that target yield projections should be considered as a profitable practice in the production of corn.

Program 3.2 runs (i) (ii) (iii) and (iv) included an increase in the cost of producing grain corn due to excess moisture drying, otherwise the approach was similar to Program 3.1A. The overall effect of the increased cost of production and the restricted delivery to the Gimli market was that the net income generated by Program 3.2 was lower than the net income realized by Program 3.1A.

Modified Program 3.2 runs (i) and (iv) included the increased cost of drying grain corn when the target yield practice was followed. In view of the fact that we have already established by Program 3.2 that increasing the cost of producing corn activity 1 and restricting corn sale to Gimli did not affect the optimum production plan of the case farm and making use of the already established fact that corn process 11 was a better corn production activity than corn activity 1, it was decided that two runs would be sufficient for modified Program 3.2. The two runs showed a net income higher than the ones returned by Program 3.2, further confirming the fact that Corn 11 was a better process for producing corn than corn activity 1.

In concluding, the series of solution generated by Program 3 revealed that due to varying percentage quantity of grain corn marketed through Gimli, the optimum value of the objective function was reduced in all the different runs as compared with the runs without restrictions. But the optimum production plan remained the same as when no restriction was placed on the sale to Gimli. This indicates that even under the conditions of increasing cost of production due to excess moisture removal and restricted sale to the Gimli distillery, grain corn is still able to compete favourably with other conventional crops.

Program Solutions with Increasing Cost of Production and no Marketing Outlet for Gimli Grain Corn Reject - Program 4

This Program examines a more realistic pattern of production, where farmers are faced with increasing costs of production and market failure. In order to achieve this objective the program continued to restrict the quantity of grain corn that could be sold to the Gimli distillery and in addition the Gimli corn rejects were considered to have no market outlet. Corn activity 1 was used with increased costs of production due to excess moisture removal. Both minimum and maximum restraints on production activities were included in the Program.

The Program solution is as shown in Table XV. Program 4 run (i) restricted the sale of grain corn to Gimli at 80 per cent. The result indicated the same optimum production plan as discussed under "OPTIMUM PLAN FOR THE CASE FARM", that is, Program 1 run (i). This included 854 acres of corn 1, 1,000 acres of barley, 200 acres of rye, 206 acres of wheat, 253 acres of sunflowers, 200 acres of flaxseed and 160 acres

TABLE XV

SOLUTION DATA: PROGRAM 4

	Unit	---- Results ----		
	Run:	i (80%)	ii(50%)	iii (30%)
Optimum Production Plan				
Corn I	acres	854.37	200.00	200.00
Barley	acres	1,000.00	1,000.00	1,000.00
Rye	acres	200.00	200.00	200.00
Wheat	acres	205.98	200.00	200.00
Sunflowers	acres	253.21	500.00	500.00
Flaxseed	acres	200.00	613.56	613.56
Rapeseed	acres	160.00	160.00	160.00
Total acreage	acres	2,873.56	2,873.56	2,873.56
Resources Used				
Owned Land	acres	1,833.56	1,833.56	1,833.56
Rented Land	acres	1,040.00	1,040.00	1,040.00
Personal Savings	dollars	54,130.00	54,130.00	54,130.00
Borrowed Capital	dollars	32,036.62	14,088.04	14,088.04
Total Labour	hours	16,550.00	16,196.84	16,196.84
Tillage Labour	hours	1,788.22	1,810.95	1,810.95
Fertilizer Labour	hours	683.91	683.91	683.91
Spraying Labour	hours	647.48	633.17	633.17
Row Crop Cultivation Labour	hours	809.64	511.70	511.70
Harvesting Labour	hours	3,484.21	3,615.85	3,615.85
Supervision Labour	hours	336.21	336.21	336.21

TABLE XV (continued)

	Unit	Results Run: i (80%)	ii (50%)	iii (30%)
Maximum Harrowing Labour	hours	772.00	772.00	772.00
Maximum Seeding Labour	hours	1,322.88	1,272.34	1,272.34
Maximum Corn Seeding Labour	hours	264.00	61.80	61.80
Unused Resources				
Owned Land	acres	6.44	6.44	6.44
Supervision Labour	hours	14.79	14.79	14.79
Maximum Seeding Labour	hours	237.12	287.66	287.66
Shadow Prices of Limiting Resources				
Personal Savings	$/dollar	0.04	0.04	0.04
Harrowing Labour	$/hour	20.04	13.15	13.15
Corn Seeding Labour	$/hour	4.90	--	--
Optimum Value of the Objective Function	dollars	30,227.16	21,260.05	17,532.69

of rapeseed.

The net income of $30,227.16 generated by Program 4 run (i), was lower than the net income realized by a similar Program, that is, Program 3.2 run (i) which netted $43,164.36. Both Programs reflected the increased cost of production due to excess moisture drying, but in Program 4 run (i) corn reject from Gimli were considered unsaleable. In view of the fact that the Program still found it profitable to grow 854 acres of corn under this set of restrictions, we may interpret this to mean that grain corn was still competitive when compared with the other conventional crops.

Program 4 run (ii) included a restriction of 50 per cent sale to the Gimli distillery, otherwise the other set of restrictions discussed under Program 4 run (i) also applied. The result generated by this run showed a change in our basis as represented in Program 4 run (i). The optimum production plan under Program 4 run (ii) included only 200 acres of corn, 1,000 acres of barley, 200 acres of rye, 200 acres of wheat, 500 acres of sunflowers, 614 acres of flaxseed and 160 acres of rapeseed. Four crops barley, rye, sunflowers and rapeseed were produced at their respective maximum level. It is interesting to note that while the acreage of corn decreased the acreages of sunflowers and flaxseed increased. There was a decrease of about six acres in the acreage of wheat. If the partial budgeting approach were to be used, the grain corn net return per acre was -$21.21. This indicates that the Program could have completely neglected the production of grain corn except for the minimum restraint that forced 200 acres into the Program. Under these circumstances it did not pay to grow grain corn as it was not competitive with the other grains like barley, flaxseed and rapeseed. The optimum value of the objective function was $21,260.05, which was $8,967.11 less than the one achieved by Program 4 run (i).

Program 4 run (iii) restricted the sale of corn to the Gimli market at 30 per cent. The optimum production plan was similar to that in Program 4 run (ii) except that the net income was further decreased. The same interpretation given under Program 4 run (ii) applied to this run.

Summarizing therefore we find that under increasing costs of production and restricted sales to the Gimli market with no market outlet for Gimli corn reject, it was only at the 80 per cent restricted sale to Gimli that corn was still competitive with other crops. Even at this level, there was a significant decrease in the net income generated by the Program.

Program Solution to Sensitivity Analysis - Program 5

A complete interpretation of a farm plan developed through linear programming model requires investigation of the stability of the plan. A useful insight into the planning situation is always provided if we are able to answer a question like; how would changes in price relationships affect the solution generated by the case model? This was the purpose for the formulation of Program 5. The sensitivity analysis was performed with grain corn 1 (as practiced on the case farm). This was considered necessary because corn activity 11 which was a target yield predictions, could not, at the present time be verified by experimental data in Manitoba.

The solution to Program 5 run (i) is presented in Table XVI. In this run the minimum restraint placed on corn production was removed and the 80 per cent sale restriction was placed on grain corn sold to the Gimli distillery. The Gimli price paid per bushel was reduced by ten cent increments until a total deduction of 80 cents was made while the price of Gimli corn reject sold for feed was held constant at $1.30 per bushel.

Between the price of $1.60 and $1.30 the solution basis did not change, that is, the optimum production plan was still 854 acres of corn, 1,000 acres of barley, 200 acres of rye, 206 acres of wheat, 253 acres of sunflowers, 200 acres of flaxseed and 160 acres of rapeseed. However, as expected, the net income generated decreased as the prices decreased; for instance while the net income generated when the Gimli grain corn price was at $1.60 was $45,535.60 the net income generated with a price of $1.30 was $30,608.07.

The basis started to change when the price of grain corn at the Gimli distillery fell to $1.20, the optimum production plan was then 589 acres of corn, 1,000 acres of barley, 200 acres of rye, 200 acres of wheat, 500 acres of sunflowers, 225 acres of flaxseed and 160 acres of rapeseed. The net income generated was $26,586.63.

At a price of $1.20 it was no longer profitable to grow 854 acres of corn, instead 589 acres was optimum and more sunflowers were grown with a small increase in the acreage of flaxseed. A reduction of six acres in wheat production was found necessary.

As the price fell to $1.10 it was no longer profitable to grow any acreage of corn, instead flaxseed acreage was increased to 814 acres,

TABLE XVI

SOLUTION DATA: PROGRAM 5 RUN i

	Unit	Gimli Prices in Dollars	1.60	1.20	1.10
<u>Optimum Production Plan</u>					
Corn 1	acres		854.37	588.68	---
Barley	acres		1,000.00	1,000.00	1,000.00
Rye	acres		200.00	200.00	200.00
Wheat	acres		205.98	200.00	200.00
Sunflowers	acres		253.21	500.00	500.00
Flaxseed	acres		200.00	224.88	813.56
Rapeseed	acres		160.00	160.00	160.00
Total acreage			2,873.56	2,873.56	2,873.56
<u>Optimum Value of the Objective Function</u>	dollars		45,535.60	26,586.63	25,358.06
Gimli price at $1.50	dollars		40,559.76	--	--
Gimli price at $1.40	dollars		35,583.91	--	--
Gimli price at $1.30	dollars		30,608.07	--	--
Gimli price at $1.00	dollars		--	--	25,358.06
Gimli price at $0.90	dollars		--	--	25,358.06
Gimli price at $0.80	dollars		--	--	25,358.06

and this basic solution continued to persist for further decreases in the Gimli price down to 80 cents. The net income in each case was $25,358.06.

The results obtained from the Program 5 run (i) indicated that between the prices of $1.60 and $1.30, grain corn was found to be competitive with the other conventional crops as the basic solution obtained was by no means different from the basic solution generated by the original case model - Program 1 run (i). Although at a price of $1.20 there was a slight change in the optimum production plan as grain corn acreage was reduced by 265 acres, this indicated that at this price level, the value of the objective function will be better attained by increasing the acreage of sunflowers, however grain corn was still competitive with the other grains. But at a price of $1.10 and below, grain corn was completely dropped from the optimum production plan as it was no longer competitive.

The solution to Program 5 run (ii) is tabulated in Table XVII. The minimum restraint on corn production was removed. In view of the fact that we had proved that under increasing cost of production due to excess moisture drying and 80 per cent restricted sale of grain corn to the Gimli distillery with no other outlet for grain corn reject from Gimli, grain corn was still found competitive with the other grains so in Program 5 run (ii), a decision was made to use a 50 per cent restriction on sales to the Gimli distillery. The Gimli price for grain corn was kept constant at $1.60 while the price of Gimli reject corn sold for feed was varied from $1.30 to 50 cents by decreasing the price by ten cents at a time.

TABLE XVII

SOLUTION DATA: PROGRAM 5 RUN ii

	Unit	Feed Price in Dollars	1.30	.80	.60
<u>Optimum Production Plan</u>					
Corn 1	acres		854.37	607.58	----
Barley	acres		1,000.00	1,000.00	1,000.00
Rye	acres		200.00	200.00	200.00
Wheat	acres		205.98	205.98	200.00
Sunflowers	acres		253.21	500.00	500.00
Flaxseed	acres		200.00	200.00	813.56
Rapeseed	acres		160.00	160.00	160.00
Total Acreage	acres		2,873.56	2,873.56	2,873.56
<u>Optimum Value of the Objective Function</u>	dollars		41,057.34	28,709.22	25,358.06
Gimli price at $1.20	dollars		38,569.42	--	--
Gimli price at $1.10	dollars		36,081.50	--	--
Gimli price at $1.00	dollars		33,593.58	--	--
Gimli price at $0.90	dollars		31,105.65	--	--
Gimli price at $0.70	dollars		--	26,939.95	--
Gimli price at $0.50	dollars		--	--	25,358.06

The results obtained signified that there was no change in the basis between a feed price of $1.30 and 90 cents. The optimum production plan was like Program 1 run (i) although as expected the net income generated decreased as the price of feed decreased.

The basis started to change as the price for feed corn dropped to 80 cents. It was found profitable to decrease the production of grain corn by 246 acres (from 854 acres to 608 acres). Sunflowers were produced at the maximum allowed by the Program, that is, 500 acres. As the price fell to 60 cents the basis completely changed as corn was dropped by the program and flaxseed was produced on 814 acres.

The results indicated that at a feed price between $1.30 and 90 cents with 50 per cent restricted sale to the Gimli distillery, grain corn was found to be competitive with the other conventional crops as the optimum production plan was the same as the one generated by Program 1 run (i). Although the basis changed, at a feed price between 80 cents and 70 cents grain corn was still competitive with the other grains as it was sunflowers and not the cereals and oilseed crops that substituted for grain corn. Grain corn was not competitive at a price of 60 cents and below where it dropped from the Program.

The solution to Program 5 run (iii) is presented in Table XVIII. The minimum restraint on grain corn production was lifted and the 80 per cent grain corn restricted sale to Gimli was utilized by this run. Both prices of grain corn marketed through the Gimli distillery and grain corn reject sold for feed were allowed to vary simultaneously by successive decreases of ten cents and eight cents respectively, until a total of one dollar was deducted from the Gimli

TABLE XVIII

SOLUTION DATA: PROGRAM 5 RUN iii

	Unit				
		Gimli Price	1.60	1.30	1.20
		Feed Price	1.30	1.06	.98
<u>Optimum Production Plan</u>					
Corn 1	acres		854.37	607.58	--
Barley	acres		1,000.00	1,000.00	1,000.00
Rye	acres		200.00	200.00	200.00
Wheat	acres		205.98	205.98	200.00
Sunflowers	acres		253.21	500.00	500.00
Flaxseed	acres		200.00	200.00	813.56
Rapeseed	acres		160.00	160.00	160.00
Total Acreage	acres		2,873.56	2,873.56	2,873.56
<u>Optimum Value of the Objective Function</u>	dollars		45,535.60	28,426.14	25,358.06
Gimli and Feed Prices at $1.50 and 1.22	dollars		39,763.62	--	--
Gimli and Feed Prices at $1.40 and 1.14	dollars		33,991.64	--	--
Gimli and Feed Prices at $1.10 and 0.90	dollars		--	--	25,358.06
Gimli and Feed Prices at $1.00 and 0.82	dollars		--	--	25,358.06
Gimli and Feed Prices at $0.90 and 0.74	dollars		--	--	25,358.06
Gimli and Feed Prices at $0.80 and 0.66	dollars		--	--	25,358.06
Gimli and Feed Prices at $0.70 and 0.58	dollars		--	--	25,358.06
Gimli and Feed Prices at $0.60 and 0.50	dollars		--	--	25,358.06

price and 80 cents from the feed price. The result was similar to that obtained in Program 5 run (ii). When the combination of Gimli prices and feed prices were reduced from \$1.60 and \$1.30 to \$1.40 and \$1.14 respectively, the basis for our solution did not change. The basis however changed slightly at a combination of Gimli prices and feed prices of \$1.30 and \$1.06 respectively and the solution was similar to the Program 5 run (ii) with 608 acres of corn produced. At any other combinations of Gimli prices and feed prices it was no longer profitable to grow corn. The interpretation was exactly the same as Program 5 run (ii) as corn was found competitive at a combined Gimli and feed price of \$1.60 and \$1.30 to \$1.30 and \$1.06 respectively, while grain corn was not found competitive at a combined price of \$1.20 and 98 cents and below.

Table XIX presents the solution data for Program 5 run (iv). All the minimum restraints placed on each crop were removed. The different c_j values of grain corn remained constant while an estimate of farm prices based on recent increases in the world market was used for the c_j values of all other crops as shown in Chapter IV, Table XI. A restricted sale of 80 per cent and 50 per cent respectively was placed on grain corn marketed through the Gimli distillery.

The optimum production plan in each case was found to be 854 acres of corn, 200 acres of rye, 474 acres of wheat, 500 acres of sunflowers, 685 acres of flaxseed and 160 acres of rapeseed. The value of the objective function was \$67,944.96 and \$63,466.71 for 80 per cent and 50 per cent respectively for the restricted grain corn sales to Gimli. It is interesting to note that at these new prices, barley

TABLE XIX

SOLUTION DATA: PROGRAM 5 RUN iv

	Unit	80%	50%
Optimum Production Plan			
Corn I	acres	854.37	854.37
Rye	acres	200.00	200.00
Wheat	acres	473.85	473.85
Sunflowers	acres	500.00	500.00
Flaxseed	acres	685.34	685.34
Rapeseed	acres	160.00	160.00
Total acreage	acres	2,873.56	2,873.56
Resources Used			
Owned Land	acres	1,840.00	1,840.00
Rented Land	acres	1,033.56	1,033.56
Personal Savings	dollars	54,130.00	54,130.00
Borrowed Capital	dollars	29,490.87	29,490.87
Total Labour	hours	16,844.66	16,844.66
Tillage Labour	hours	1,814.87	1,814.87
Fertilizer Labour	hours	683.91	683.91
Spraying Labour	hours	652.17	652.17
Row Crop Cultivating Labour	hours	1,000.04	1,000.04
Harvesting Labour	hours	3,504.49	3,504.49
Supervision Labour	hours	336.21	336.21
Maximum Harrowing Labour	hours	772.00	772.00
Maximum Seeding Labour	hours	1,353.48	1,353.48
Maximum Corn Seeding Labour	hours	264.00	264.00
Resources Left Unused			
Supervision Labour	hours	14.79	14.79
Maximum Seeding Labour	hours	206.52	206.52
Shadow Prices of Limiting Resources			
Personal Savings	dollars	.04	.04
Harrowing Labour	hours	52.98	52.98
Maximum Seeding Labour	hours	24.22	7.26
Optimum Value of the Objective Function	dollars	67,944.96	63,466.71

disappeared completely from the optimum production plan while wheat, flaxseed and sunflowers production were increased. Corn was maintained at the level of production imposed by the constraint of available corn seeding labor. This indicated that grain corn at a restricted quantity sale of 50 per cent and 80 per cent to Gimli, but retaining the old price of \$1.60 paid by Gimli and \$1.30 paid for feed was still competitive with other crops when their prices were increased.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Linear programming[1] was the methodology used in this study. The method is a procedure for providing a normative answer to problems which can be formulated in a manner that will permit the application of the linear programming method to solving the problem. For instance in this study, linear programming provided what ought to be the optimum production plan for the case farm subject to the set of restraints imposed upon the program without necessarily indicating what type of adjustments in farm organization would be necessary to attain the optimum production plan. But, since the nature of the problem examined by this study was normative, linear programming was found to be an adequate tool for the analysis.

The results generated by a linear programming analysis are only as good as the quality of the input-output coefficients fed into the program, hence an evaluation of the model will be necessary in order to determine how the conceptual model approximates reality.

Evaluation of the Conceptual Model

This study utilized a model which attempted to simulate the operation of a firm which was solely engaged in the production of crops. For the purpose of examining the accuracy of the model in approximating

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[1]Reference is hereby made to Beneke and Winterboer, op. cit. pp. 1-6, for an excellent review of limitations in the use of linear programming for farm planning.

the operations on the case farm we shall examine some of the activities and restraint levels that came into play in the case model.

Price levels. All the c_j values of the conventional grain quota selling activities were ten year averages (1960-1970) calculated from the Manitoba Agriculture 1970 year book, while the c_j values of the livestock feed selling activity as well as the grain corn selling activity to the Gimli distillery were three year averages (1969-1971) supplied by the feed industry and the Gimli distillery respectively. While a longer price series may have been desirable the data were not available. The feed mills contacted could not supply accurate data beyond 1969 while the Gimli distillery did not commence operations until 1969. The prices used to perform the last run of sensitivity analysis were rough estimates based on recent price increases in world grain markets. It should be recognized that the solutions obtained by this study become accurate only when the level of prices assumed by the model are approached.

Resource supplies and restraint levels. The model utilized the owned and hired resources at the disposal of the manager of the case farm. The linear programming model was designed to utilize the resources existing on the case farm and was not modified to be applicable to farms with fewer resources.

The various percentage restraints placed on corn marketed through the Gimli distillery were arbitrary. The purpose was designed to be able to test the effect of restricted levels of grain corn marketed through Gimli on the optimum solution and also examine the effect of the competitiveness of grain corn with other crops. The subjective restraints placed on the case model are those expressed by the manager of the case farm. For these reasons, it would be necessary to exercise caution in applying the results of this study to any other farm business unless consideration was given to analysing the similartiy or difference between other farms and the one studied.

Level of technology assumed. Most of the data necessary for the calculation of the cropping activity coefficients were collected from the farm record book of the case farm. But the data for calculating the coefficients of corn activity 11 which is the target yield prediction were supplied by the Provincial Soil Testing Laboratory. In all cases the various coefficients were carefully calculated. The technology of crop production used in the model was assumed constant as given because the calculated input-output coefficients which fix the technical characteristics of production were restricted to the case farm. The uniqueness of the data regarding cropping technology should be recognized if the results were to be applied to other farms engaged in crop production.

Static nature of the model. The static nature of the case model, implicitly assumed that demand, production and supply functions were constant and given. Throughout this study attention was centered on how grain corn competes with the other conventional crops in the context of profit maximization. This assumed that the time factor that might be necessary to make the adjustment in the farm organization in order to achieve the optimum combination of enterprises could be made within a production year, but a longer period of time may be found necessary.

Conclusions

The following conclusions were reached on the basis of the solutions generated by the linear programming case model.

Under the conditions imposed and specified by the model the case-study farm could maximize net income by producing the various combination of crop enterprises as proposed in Chapter V Table XII. Grain corn was found to be competitive with other conventional crops and contributed in a significant way to maximizing the farmer's income. It was recommended that the case farm could adopt the productive practice needed to obtain a target yield and thereby increase profits over those obtained by practices currently followed. This recommendation must be taken with caution however as no experimental data under Manitoba conditions were available to confirm whether costs and yields estimated to obtain target yield were attainable. In any event it was found that the limiting resource affecting an increase in the quantity of grain corn produced was the available corn seeding labor.

Furthermore, it was found that under increased cost of production and restricted sale of grain corn to the Gimli distillery, the same combination of crop enterprises was recommended to maximize the case farm net income but the effect of the restricted sale was decreased in the amount of net income obtained under no restrictions. Under these circumstances, it was advisable to aim at producing a corn crop 80 per cent of which would be acceptable to the Gimli market. If conditions were such that there was no alternate market for corn reject by the

Gimli distillery the same optimum combination of enterprises could be recommended provided 80 per cent of the quantity of corn produced could meet the specifications of the Gimli distillery. Otherwise, a substantial increase in the production of sunflowers and flaxseed would be recommended as indicated in Chapter V, Table XV with either a reduction in grain corn acreage or corn would be removed from the cropping program.

The stability of the plan recommended for the case farm was tested and the range of prices where the plan was stable and unstable were presented in Chapter V, Tables XVI to XIX. Provided the expected prices can be predicted within reasonable limits these Tables would be helpful in indicating how production should be organized.

It is realized that a study of this nature is bound to have short comings. However if the assumptions used in building the model are carefully specified and realistic and, if it is remembered that the accuracy of the results obtained by this study are closely linked with how the real world situation approaches those defined by the model; then the research has contributed to an understanding of the place of grain corn in a cropping program in competition with the other conventional crops on the case farm.

Recommendations for Further Study

The production of grain corn in Manitoba could make a significant contribution to farm income and provide an alternate crop for non-quota production of both cash and feed crops. The place of grain corn in Manitoba agriculture cannot be properly appraised given the present level of knowledge with respect to the soil, climatic and agronomic factors affecting corn production. Further research into the economic feasibility of grain corn production is also required before grain corn could be recommended for general adoption in those arears of the province where soil and climatic factors are suitable. Some suggestions for further study would include:

1. detailed agronomic research in corn production techniques such as fertilizer use, disease control and cultural practice should be examined;
2. extended research over a broader based sample of farms in order that corn production can be assessed within a framework different from the resource and technology limits used in this study;
3. the place of livestock either as a complementary or supplementary enterprise along with a cropping program that included corn in the rotation; and
4. a multi-period linear programming technique might be used to study the time-factor effect on the adjustment in farm organization required to include corn along with other conventional crops combined with a livestock enterprise.

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APPENDIX

TABLE A.1

HOURLY OPERATIONAL LABOR REQUIREMENTS PER ACRE

	Operation	Conventional Crops*	Sunflowers	Corn
		----------- man hours -----------		
1	Tillage Labour	0.611	0.719	0.617
2	Seeding Labour	0.247	0.309	0.309
3	Harrowing Labour	0.174	0.174	0.174
4	Spraying Labour	0.218	0.238	0.238
5	Fertilizer Labour	0.238	0.238	0.238
6	Cultivating Labour	-	0.731	0.731
7	Harvesting Labour	1.337	1.014	1.014
8	Supervision Labour	0.117	0.117	0.117
	Total Labour	2.942	3.539	3.437

*includes Wheat, Rye, Barley, Flaxseed, and Rapeseed.

TABLE A.2

CROP EXPENSES PER ACRE

Item	Wheat	Oats	Barley	Sunflower	Corn 1	Corn 11	Rapeseed	Flax-Seed	Rye
				---------	dollars	---------			
Fertilizer	2.37	1.92	2.64	3.13	5.80	9.00	2.31	1.50	1.92
Anhydrous Ammonia	2.12	2.59	2.86	2.16	3.38	3.38	-	2.35	2.59
Sprays	0.25	-	-	-	-	-	-	-	-
Herbicides-Dust	1.00	0.46	0.79	1.69	0.56	0.56	0.93	-	0.46
Custom Spraying	1.10	1.00	0.27	0.33	2.18	2.18	1.00	0.06	1.00
Custom Combining	-	-	-	1.66	-	-	-	-	-
Hauling and Trucking	-	-	-	0.09	1.97	1.97	-	-	-
Freight and Express Charges	-	-	-	-	1.96	1.96	-	-	-
Seed	2.38	2.16	1.28	0.78	1.88	1.88	1.90	2.49	1.81
Purple Gas	0.23	0.24	0.29	0.31	0.91	0.91	0.30	-	0.24
Liquid Propane	-	-	0.22	0.35	2.36	3.36	-	-	-
Oil	-	-	-	-	0.03	0.03	-	-	-
Truck repairs and Maintenance	1.00	1.00	0.98	1.10	1.10	1.10	0.96	1.00	1.00
Tractor repairs and Maintenance	1.47	1.43	1.40	1.67	1.69	1.69	1.36	1.43	1.43
Combine repairs and Maintenance	1.31	1.27	1.25	1.50	1.48	1.48	1.37	1.31	1.27
Other Equipments repairs and Maintenance	1.87	1.99	1.83	2.27	2.24	2.24	1.86	-	1.99
Crop insurance	-	0.51	-	-	-	-	-	-	0.51
*Fixed Cost	6.89	8.16	7.95	10.11	18.84	18.84	7.43	7.00	8.16
**Total	21.98	22.73	21.75	27.14	46.37	50.58	19.44	18.14	22.38

*Includes depreciation on Buildings, Machinery and Equipment at 9% investment on Buildings, Machinery and Equipment at 8% and Land Tax of $2.00 per acre.

**Total do not add up due to rounding error.

TABLE A.3

CROP YIELD PER ACRE

Crop	1968	1969	1970	1971	Average
			----------bushels ----------		
Wheat	25.70	26.70	26.33	35.00	28.43
Oats	90.20	40.00	-	80.00	70.07
Barley	56.60	41.10	51.98	69.00	54.67
Flax	15.30	11.30	11.87	-	12.82
Rapeseed	25.50	17.58	18.06	30.00	22.79
Corn	-	58.50	57.21	59.00	58.24
Rye	30.75	49.50	40.50	59.25	45.00
			----------pounds ----------		
Sunflowers	-	953.00	952.66	952.83	952.83

TABLE A.4

YEARLY FARM PRICES FOR
MANITOBA CROPS

Crop Year	Wheat*	Oats*	Barley*	Flax*	Rye*	Rapeseed*	Corn**	Sunflowers*
		- - dollars per bushel - -						cents per pound
1960	1.61	0.62	0.84	2.75	0.87	2.00	-	.045
1961	1.78	0.63	1.05	3.30	1.08	1.80	-	.045
1962	1.70	0.59	1.00	3.00	1.05	-	-	.055
1963	1.71	0.55	0.92	2.85	1.30	2.50	-	-
1964	1.63	0.60	1.02	2.95	1.05	2.70	-	.050
1965	1.65	0.71	1.05	2.69	1.04	2.45	-	.0575
1966	1.78	0.75	1.10	2.70	1.08	2.45	-	.060
1967	1.64	0.69	0.89	3.08	1.08	1.90	-	.045
1968	-	-	0.79	2.84	1.00	1.88	-	.050
1969	1.45	0.55	-	2.57	0.87	2.40	1.60	.055
1970	1.45	0.60	1.00	-	-	2.35	1.69	.060
1971	-	-	-	-	-	-	1.50	-
Average	1.64	0.629	0.882	2.873	1.042	2.239	1.60	.052

*Data collected from Yearbook of Manitoba Agriculture, 1970. The lowest annual price received was omitted in each case to arrive at the 10 year average.

**Data collected from Calvert of Canada Ltd. (Gimli distillery).

TABLE A.5

NUMBER OF LIVESTOCK ON FARM
IN SOUTH-CENTRAL MANITOBA
1956-1966*

Year	Sub-Division	Horses	Cattle: Total	Cattle: Cows and Heifers Milking or to be Milked	Sheep	Pigs	Hens and Chickens: Total	Hens and Chickens: Hens and Pullets
1956	Morris	308	3,800	1,525	72	5,857	190,072	49,757
	Roland	213	3,261	630	320	1,702	63.644	18.100
	Thompson	350	4,742	736	556	2,466	55,997	15,615
	Dufferin	769	12,980	2,745	1,828	6,418	127,894	38,586
	Total	1,640	24,873	5,636	2,776	16,443	437,607	122,058
1961	Morris	175	4,683	1,398	107	7,458	215,873	62,269
	Roland	100	3,449	498	121	2,825	63,639	21,709
	Thompson	267	6,404	732	579	4,623	41,094	12,503
	Dufferin	543	14,139	2,391	1,654	10,898	149,286	54,567
	Total	1,085	28,675	5,019	2,461	25,804	469,892	151,048
1966	Morris	144	2,681	746	83	14,805	257,817	144,921
	Roland	95	1,861	211	90	2,709	35,651	13,040
	Thompson	216	6,396	557	154	5,285	19,393	6,727
	Dufferin	508	13,208	1,889	841	12,709	88,149	46,459
	Total	963	24,146	3,403	1,168	35,508	401,010	211,147

*Source: 1956, 1961 and 1966 Census of Canada Agriculture, Manitoba

FIGURE A-1

INITIAL SIMPLEX TABLEAU OF THE CASE MODEL

Restraint Number and Title	Unit	Restraint Level (b_i)	c_j:	-46.37	
			Activity Number and Title:	1 Corn 1	Row No.
			Unit	acre	
1 Owned Land	acre	≤ 1840.			1
2 Land	acre	≤ 0.		1.	2
3 Rt. Land Limit	acre	≤ 1040.			3
4 Personal Savings	dollar	≤ 54530.			4
5 Oper. Capital	dollar	≤ 0.		46.37	5
6 Borrow Lt. on Capt.	dollar	≤ 172782.			6
7 Total Lab. Supply	hour	≤ 0.		3.437	7
8 Tillage Lab. Supply	hour	≤ 0.		0.617	8
9 Harrow Lab. Supply	hour	≤ 228.		0.174	9
10 Seeding Lab. Supply	hour	≤ 234.		0.309	10
11 Fert. Lab. Supply	hour	≤ 0.		0.238	11
12 Spraying Lab. Supply	hour	≤ 114.		0.237	12
13 Row Crop. Cult. Lab. Sup.	hour	≤ 312.		0.731	13
14 Harvesting Lab. Sup.	hour	≤ 282.		1.014	14
15 Operators Sup. Lab. Sup.	hour	≤ 351.		0.117	15
16 Max. Harrow Lab.	hour	≤ 772.		0.174	16
17 Max. Seeding Lab.	hour	≤ 1560.		0.309	17
18 Max. Corn Seed. Lab.	hour	≤ 264.		0.309	18
19 Corn Supply	bushel	≤ 0.		-58.24	19
20 Oat Supply	bushel	≤ 0.			20
21 Barley Supply	bushel	≤ 0.			21
22 Rye Supply	bushel	≤ 0.			22
23 Wheat Supply	bushel	≤ 0.			23
24 Sunflower Supply	pound	≤ 0.			24
25 Flax Supply	bushel	≤ 0.			25
26 Rape-Seed Supply	bushel	≤ 0.			26
27 Corn Reject Supply	bushel	≤ 0.			27
28 Assignable Acres	acre	≤ 0.		-1.	28
29 Oat Quota Sup.	bushel	≤ 0.			29
30 Barley Quota Sup.	bushel	≤ 0.			30
31 Rye Quota Sup.	bushel	≤ 0.			31
32 Wheat Quota Sup.	bushel	≤ 0.			32
33 Flax Quota Sup.	bushel	≤ 0.			33
34 Rape Quota Sup.	bushel	≤ 0.			34
35 Corn Pr. Max. Lt.	acre	≤ 1000.		1.	35
36 Oat Pr. Max. Lt.	acre	≤ 50.			36
37 Barley Pr. Max. Lt.	acre	≤ 1000.			37
38 Rye Pr. Max. Lt.	acre	≤ 200.			38
39 Wheat Pr. Max. Lt.	acre	≤ 1000.			39
40 Sunflower Pr. Max. Lt.	acre	≤ 500.			40
41 Flax Pr. Max. Lt.	acre	≤ 1000.			41
42 Rape Pr. Max. Lt.	acre	≤ 160.			42
43 Corn Pr. Min. Lt.	acre	≥ 200.		1.	43
44 Barley Pr. Min. Lt.	acre	≥ 200.			44
45 Wheat Pr. Min. Lt.	acre	≥ 200.			45
46 Sunflower Pr. Min. Lt.	acre	≥ 100.			46
47 Flax Pr. Min. Lt.	acre	≥ 200.			47

FIGURE A-1 (continued)

Restraint Number	Activity Number and Title:	2 Corn 2	3 Oat	4 Barley	5 Rye	6 Wheat	Row No.
	c_j:	-50.58	-22.73	-21.75	-22.38	-21.98	
	Unit	acre	acre	acre	acre	acre	
1							1
2		1.	1.	1.	1.	1.	2
3							3
4							4
5		50.58	22.73	21.75	22.38	21.98	5
6							6
7		3.437	2.942	2.942	2.942	2.942	7
8		0.617	0.611	0.611	0.611	0.611	8
9		0.174	0.174	0.174	0.174	0.174	9
10		0.309	0.247	0.247	0.247	0.247	10
11		0.238	0.238	0.238	0.238	0.238	11
12		0.237	0.218	0.218	0.218	0.218	12
13		0.731					13
14		1.014	1.337	1.337	1.337	1.337	14
15		0.117	0.117	0.117	0.117	0.117	15
16		0.174	0.174	0.174	0.174	0.174	16
17		0.309	0.247	0.247	0.247	0.247	17
18		0.309					18
19		-70.					19
20			-70.07				20
21				-54.67			21
22					-45.		22
23						-28.43	23
24							24
25							25
26							26
27							27
28		-1.	-1.	-1.	-1.	-1.	28
29							29
30							30
31							31
32							32
33							33
34							34
35		1.					35
36			1.				36
37				1.			37
38					1.		38
39						1.	39
40							40
41							41
42							42
43		1.					43
44				1.			44
45						1.	45
46							46
47							47

FIGURE A-1 (continued)

Restraint Number	Activity Number and Title:	7 Sun-flower	8 Flax	9 Rape	10 Sell Oat Quota	11 Sell Bar-ley Quota	Row No.
	c_j:	-27.14	-18.14	-19.44	.629	.882	
	Unit	acre	acre	acre	bushel	bushel	
1							1
2		1.	1.	1.			2
3							3
4							4
5		27.14	18.14	19.44			5
6							6
7		3.539	2.942	2.942			7
8		0.719	0.611	0.611			8
9		0.174	0.174	0.174			9
10		0.309	0.247	0.247			10
11		0.238	0.238	0.238			11
12		0.237	0.218	0.218			12
13		0.731					13
14		1.014	1.337	1.337			14
15		0.117	0.117	0.117			15
16		0.174	0.174	0.174			16
17		0.309	0.247	0.247			17
18							18
19							19
20					1.		20
21						1.	21
22							22
23							23
24		-952.83					24
25			-12.82				25
26				-22.79			26
27							27
28		-1.	-1.	-1.			28
29					1.		29
30						1.	30
31							31
32							32
33							33
34							34
35							35
36							36
37							37
38							38
39							39
40		1.					40
41			1.				41
42				1.			42
43							43
44							44
45							45
46		1.					46
47			1.				47

FIGURE A-1 (continued)

Restraint Number	Activity Number and Title:	12 Sell Rye Quota	13 Sell Flax Quota	14 Sell Rape Quota	15 Sell Wheat Quota	Row No.
	c_j:	1.042	2.873	2.239	1.64	
	Unit	bushel	bushel	bushel	bushel	
1						1
2						2
3						3
4						4
5						5
6						6
7						7
8						8
9						9
10						10
11						11
12						12
13						13
14						14
15						15
16						16
17						17
18						18
19						19
20						20
21						21
22		1.				22
23					1.	23
24						24
25			1.			25
26				1.		26
27						27
28						28
29						29
30						30
31		1.				31
32					1.	32
33			1.			33
34				1.		34
35						35
36						36
37						37
38						38
39						39
40						40
41						41
42						42
43						43
44						44
45						45
46						46
47						47

FIGURE A-1 (continued)

Restraint Number	Activity Number and Title:	16 Sell Wheat Feed	17 Sell Oat Feed	18 Sell Barley Feed	19 Sell Corn Feed	Row No.
	c_j:	1.07	.52	.73	1.30	
	Unit	bushel	bushel	bushel	bushel	
1						
2						1
3						2
4						3
5						4
6						5
7						6
8						7
9						8
10						9
11						10
12						11
13						12
14						13
15						14
16						15
17						16
18						17
19						18
20					1.	19
21			1.			20
22				1.		21
23		1.				22
24						23
25						24
26						25
27						26
28						27
29						28
30						29
31						30
32						31
33						32
34						33
35						34
36						35
37						36
38						37
39						38
40						39
41						40
42						41
43						42
44						43
45						44
46						45
47						46
						47

FIGURE A-1 (continued)

Restraint Number	Activity Number and Title:	20 Sell Sunflower	21 Sell 100% C. to Gim.	22 Sell 80% C. to Gim.	23 Sell 50% C. to Gim.	Row No.
	c_j:	.052	1.60	1.28	.80	
	Unit	bushel	bushel	bushel	bushel	
1						1
2						2
3						3
4						4
5						5
6						6
7						7
8						8
9						9
10						10
11						11
12						12
13						13
14						14
15						15
16						16
17						17
18						18
19			1.	1.	1.	19
20						20
21						21
22						22
23						23
24		1.				24
25						25
26						26
27				-.2	-.5	27
28						28
29						29
30						30
31						31
32						32
33						33
34						34
35						35
36						36
37						37
38						38
39						39
40						40
41						41
42						42
43						43
44						44
45						45
46						46
47						47

FIGURE A-1 (continued)

Restraint Number	c_j:	.48	-9.	-9.	-.05	Row No.
	Activity Number and Title:	24 Sell 30% C. to Gim.	25 Rent Personal Land	26 Rent Land	27 Borrow Personal Savings	
	Unit	bushel	bushel	acre	bushel	
1			1.			1
2			-1.	-1.		2
3				1.		3
4					1.	4
5					-1.	5
6						6
7						7
8						8
9						9
10						10
11						11
12						12
13						13
14						14
15						15
16						16
17						17
18						18
19		1.				19
20						20
21						21
22						22
23						23
24						24
25						25
26						26
27		-.7				27
28						28
29						29
30						30
31						31
32						32
33						33
34						34
35						35
36						36
37						37
38						38
39						39
40						40
41						41
42						42
43						43
44						44
45						45
46						46
47						47

FIGURE A-1 (continued)

Restraint Number	c_j:	-.085	-1.50	-1.50	-1.50	Row No.
	Activity Number and Title:	28 Borrow Capital	29 Hire Tillage Labor	30 Hire Harrow Labor	31 Hire Seeding Labor	
	Unit	dollar	hour	hour	hour	
1						1
2						2
3						3
4						4
5		-1.				5
6		1.				6
7			1.	1.	1.	7
8			-1.			8
9				-1.		9
10					-1.	10
11						11
12						12
13						13
14						14
15						15
16						16
17					1.	17
18						18
19						19
20						20
21						21
22						22
23						23
24						24
25						25
26						26
27						27
28						28
29						29
30						30
31						31
32						32
33						33
34						34
35						35
36						36
37						37
38						38
39						39
40						40
41						41
42						42
43						43
44						44
45						45
46						46
47						47

FIGURE A-1 (continued)

	c_j:	-1.50	-1.50	-1.50	-1.50	
Restraint Number	Activity Number and Title:	32 Hire Fert. Labor	33 Hire Spray Labor	34 Hire Cult. Labor	35 Hire Harv. Labor	Row No.
	Unit	hour	hour	hour	hour	
1						1
2						2
3						3
4						4
5						5
6						6
7		1.	1.	1.	1.	7
8						8
9						9
10						10
11		-1.				11
12			-1.			12
13				-1.		13
14					-1.	14
15						15
16						16
17						17
18						18
19						19
20						20
21						21
22						22
23						23
24						24
25						25
26						26
27						27
28						28
29						29
30						30
31						31
32						32
33						33
34						34
35						35
36						36
37						37
38						38
39						39
40						40
41						41
42						42
43						43
44						44
45						45
46						46
47						47

FIGURE A-1 (continued)

	c_j:	1.30					
Restraint Number	Activity Number and Title:	36 Sell Re-ject Corn	37 Oat Transf.	38 Barley Transf.	39 Rye Transf.	40 Wheat Transf.	Row No.
	Unit	bushel	bushel	bushel	bushel	bushel	
1							1
2							2
3							3
4							4
5							5
6							6
7							7
8							8
9							9
10							10
11							11
12							12
13							13
14							14
15							15
16							16
17							17
18							18
19							19
20							20
21							21
22							22
23							23
24							24
25							25
26							26
27		1.					27
28			1.	1.	1.	1.	28
29			-12.				29
30				-40.			30
31					-30.		31
32						-8.	32
33							33
34							34
35							35
36							36
37							37
38							38
39							39
40							40
41							41
42							42
43							43
44							44
45							45
46							46
47							47

FIGURE A-1 (continued)

c_j:

Restraint Number	Activity Number and Title:	41 Flax Transf.	42 Rape Transf.	Row No.
	Unit	bushel	bushel	
1				1
2				2
3				3
4				4
5				5
6				6
7				7
8				8
9				9
10				10
11				11
12				12
13				13
14				14
15				15
16				16
17				17
18				18
19				19
20				20
21				21
22				22
23				23
24				24
25				25
26				26
27				27
28		1.	1.	28
29				29
30				30
31				31
32				32
33		-15.		33
34			-12.	34
35				35
36				36
37				37
38				38
39				39
40				40
41				41
42				42
43				43
44				44
45				45
46				46
47				47