PROGRAMMING THE ORGANIZATION AND AND CAPITAL USE FOR A CASH CROP FARM IN THE SAGINAW VALLEY AND THUMB AREA OF MICHIGAN

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PROGRAMMING THE ORGANIZATION AND CAPITAL USE FOR A CASH CROP FARM IN THE SAGINAW VALLEY AND THUMB AREA OF MICHIGAN

By

Frank Edward Dvorak

A THESIS

Submitted to the College of Agriculture of Michigan State University of Agriculture and Applied Science
in partial fulfillment of the requirements
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ABSTRACT

The major objective of this study was to analyze the organization and operation of a cash crop farm to determine the most profitable investments. A linear programming approach which incorporated a fixed asset definition was used. This model allowed for the purchase of new and different assets and the sale of existing assets in considering changes in the organization of the farm rather than assuming that the initial asset structure of the farm was fixed.

The initial farm business situation consisted of 160 acres with a total investment of $79,000; $72,000 of which was invested in land and $7,000 in machinery. The operator's debt was $21,000 and he had a net worth of $58,000 which served as collateral for borrowing capital. An upward sloping credit supply curve was specifically based on the various sources of credit, types of contracts a farmer would have access to and the institutional arrangements under which credit is supplied to farmers. The operator and his son, of high school age, constituted the initial labor supply.

The input-output data was based on currently recommended, not necessarily presently adopted cropping practices. Present prices for all inputs and outputs were projected five years in the future by extending current trends.

Alternatives considered in the program included: three levels of fertilizer use; four crops, corn, sugar beets, wheat, and navy beans; acreage restrictions for sugar beets, wheat, and navy beans; a 2-plow and a 3 to 4-plow tractor; pre-emergence weed sprays for all crops except wheat; plow plant for all crops except wheat; 2, 4, and 6-row planters and cultivators; 6 and 10-foot combines; custom hiring of combining services for navy beans and wheat; 2-row pickers and picker-shellers; custom hiring of picker or picker-sheller services; hand hoeing and mechanical thinning of sugar beets; and drying and storage of corn. The problem was formulated so any alternative could combine with any other alternative.

Substantial reorganization took place as: 160 acres of land, a 6-row planter, and a 6-row cultivator were acquired and a 2-plow tractor, a 6-foot combine, a 4-row planter and a 4-row cultivator were sold. The machinery for the optimum solution included a 2-plow tractor, a 3 to 4-plow tractor, a 2-bottom 14 inch plow, a 3-bottom 14 inch plow, a 6-row planter, a 6-row cultivator, bean puller, 8-foot disc, rake, 9-foot drill and two wagons. The crop rotation consisted of 32 acres of wheat, 136 acres of navy beans, 40 acres of sugar beets and 63 acres of corn. A pre-emergence spray was used to control weeds in corn while sugar beets were cultivated and thinned mechanically. In addition to farming, the operator held a full-time job from July 1st until the middle of March and he hired the harvesting of corn, wheat, navy beans, and sugar beets.

The conclusions of this study were that farmers should: (1) use larger equipment, (2) enlarge farm size, (3) utilize credit to a greater degree, (4) double their present use of fertilizer, and (5) crop more intensively. The labor income (not including the off-farm job) for the optimum farm was $8,176, which compares more than favorably with what the operator could make in industry.

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CHAPTER I

INTRODUCTION

Many farmers in east-central Michigan are not obtaining returns for their labor equal to that which they could obtain in industry. This study was an attempt to determine if farmers in the Saginaw Valley and Thumb area could obtain returns from their labor comparable to industrial employment.

Need for Study

The average farmer in the Michigan State University farm account studies of the Saginaw Valley and Thumb area had a labor income in 1958 of $2847[1] while the average industrial worker in the Saginaw area had an income of $5334.[2] Studies conducted in different agricultural areas of Michigan indicate that the returns from labor on farms is low, but that farmers in the Saginaw Valley and Thumb area received relatively better returns than farmers in other areas of Michigan. Table I shows what farm operator labor is earning in selected areas of Michigan in

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[1]Farming Today, Area 8 Report, Cooperating Extension Service, Department of Agricultural Economics, Michigan State University, 1959, p. 6.

[2]Employment and Earnings, United States Department of Labor, Bureau of Labor Statistics, Annual Supplement Issue, Volume 5, Number 11, p. 57.

selected years. The data are from different studies at different times and are not directly comparable but give some indication of the earnings of labor. The earnings shown in Table I are the marginal returns or the earnings on additional units of inputs,[1] not average earnings. These studies indicate that farmers would receive low returns for additional labor with present farm organization.

TABLE I

THE RETURNS FROM THE LAST MONTH OF LABOR USED AND FROM OTHER COMPLEMENTARY FACTORS OF PRODUCTION FOR SELECTED AREAS IN MICHIGAN*

Area	Earning Power of Last Month of Labor Used	Earning Power of Last Month of Labor Used Plus Other Factors of Production Used With It
	(dollars)	(dollars)
Thumb, Cash Crops, '57	307	1279
Ingham Co., Dairy, '52	30	787
Burnside Twshp., '53	113	750
Almont Twshp., '53	84	627
Ogemaw-Arenac, Beef, '53	182	606
Ogemaw-Arenac, Process Milk, '53	137	394
Ogemaw-Arenac, Fluid Milk, '53	114	546
Soil B, So-Central Mich., Dairy '53	41	706
Soil P_4, So-Mich., Dairy, '53	—	600
Soil P, So-Central Mich., Dairy, '53	—	798
Soil O, So-Central Mich., Dairy, '53	—	797

*Glenn L. Johnson, The Need for More Information on Labor Saving Technology, Department of Agricultural Economics, Michigan State University, p. 1.

[1]The assumption made here is that additional units would be worth the same as the last units used.

The returns from other factors of production are also low as suggested in the studies above and in farm account records. In fact, when interest for the entire investment is added to the labor income for farmers in the farm account studies ($3075 interest plus $2847 labor income) the yearly earnings are only slightly more than the yearly earnings of the wage earner who does not have any investment. Nevertheless, additional inputs will not increase farm earnings substantially; it would therefore seem that new organization is necessary.

Effecting a reorganization of the farm firm may or may not involve acquiring new and different assets and the disposition of some of the existing assets, depending upon the product alternatives that are technically feasible for the location and the existing resource structure of the firm. Therefore, in order to determine the optimum organization, the analysis must take into consideration capital expenditures as well as the annual out-of-pocket expenses associated with each of the alternatives that the firm might adopt in reconstituting its operations.

Because, according to a study by M. D. Brooke,[1] the area is characterized by constant returns to scale, linear programming which assumes constant input-output ratios appears adapted to the area. Linear programming also has the advantage of analyzing a large number of relationships where these relationships are specific and quantified.

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[1]M. D. Brooke, "Marginal Productivity of Inputs on Cash Crop Farms in the Thumb and Saginaw Valley Area of Michigan," Unpublished Master's Thesis, Department of Agricultural Economics, Michigan State University, 1957, p. 21.

With quantified specific alternatives, the results are based on explicit assumptions which can be analyzed. However, a methodological problem arose, since previous applications of linear programming have assumed the asset structure of the farm was fixed and capital expenditures need not be analyzed. In analyzing organizational and operational adjustment, this model must compare capital expenditures with current expenditures.

Objectives

The objectives of this study were to: (1) determine the optimum farm size, machinery combination and cropping system for a typical cash crop farm in the Saginaw Valley and Thumb area to see if the operator could obtain labor earnings comparable with those in industry, (2) incorporate a definition of fixed assets into a linear programming model which would allow all of the quantities of current expenditures and capital expenditures to vary within credit limitations as long as it was profitable, and (3) obtain an over-all view of farm investments by determining whether additional investments or disinvestments should be made in labor, crops, machines, land, corn storage or fertilizer.

The Area Involved

The farm situation analyzed is representative of a large number of the farms in the cash cropping region of the Saginaw Valley and Thumb Area of Michigan. The Saginaw Valley and Thumb area is endowed with many economic advantages: heavy industry, rich soils, and markets for high valued crops. This area embraces most of Huron, Sanilac, Tuscola, Bay and Saginaw counties.

The area is highly industrialized (mainly automobile manufacturing), influencing agriculture to a great extent because of competition for farm labor. Many industrial workers live in the country where they own and, perhaps, operate small acreages which accounts for the large number of part-time farmers and many small farms in this area. The modal size farm in the area is about 80 acres.[1]

The area is nearly level with some low depressions and narrow sandy ridges. The soils of this area were developed under very poor natural drainage conditions from loams, silty clay loams or clay loams under the influence of trees. The soils are finely textured, high in organic matter and highly productive, if drained.[2]

Cash cropping is becoming more predominant in the area. Most of the navy beans produced in the United States are grown in the Saginaw Valley and Thumb area. Brooke found in his sample, percentages of crops on tillable land as follows: navy beans 44.1%, wheat 21.0%, sugar beets 20.0%, oats 5.2%, corn 4.9%, barley 2.7%, soybeans 1.2%, alfalfa 0.5% and other crops 0.5%.[3] Though his sample was limited to farms growing sugar beets, it provides some indication of the proportion of high value crops.

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[1]United States Census of Agriculture, 1954, "Counties and State Economic Areas of Michigan," Volume 1, Part 6, 1956, 284 pp.

[2]E. P. Whiteside, I. F. Schneider, R. L. Cook, Soils of Michigan, Special Bulletin 402, Soil Science Department, Michigan State University, Jan. 1956, p. 39.

[3]Brooke, op. cit., p. 18.

The investments in land and buildings are greater than those in most other areas of Michigan with an average Michigan farm account book value of $61,408.[1] The buildings are usually painted and in good repair, and the farms give the appearance of being well-kept.

Typical Farm Situation

The typical farm situation was synthesized using data from many sources, such as surveys, farm account records, and consultations with students and faculty of Michigan State University. Data from these sources were compared and integrated into one initial farm situation from which all adjustments were made in the study. The farm size, machinery, buildings, labor, net worth, and credit closely approximate situations which would be found on many farms in the area.

Farm Size

As this study deals mainly with full-time farmers and their adjustments for their farming enterprises, the modal farm size for full-time farmers was sought and found to be 160 acres.[2] It was not surprising to find that 160 acres was modal since acreage transactions usually involve units or multiples of 40 acres.

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[1] Farming Today, Area 8 Report, op. cit.

[2] Ibid. Consultation with people acquainted with area.

Machinery

Farm account records were scrutinized and people acquainted with the area were consulted to ascertain an initial typical machinery inventory which is presented in Table II. Ten percent was added to present prices to extend current machinery price trends five years to determine the 1964 market value. Depreciation and taxes were based on the values given in Table II.

TABLE II

AGE, DEPRECIATION, TAXES AND VALUE OF THE INITIALLY OWNED MACHINERY

Machinery	Year Bought	1964 Market Values* (dollars)	Depreciation** plus Taxes, Per Year (dollars)
2-plow tractor (two)	1951	600	302
3 to 4-plow tractor	1958	3,000	330
2-14 plow	1948	100	1
3-14 plow	1954	208	47
8-foot disc	1955	150	31
4-row planter	1954	350	37
9-foot drill	1953	275	55
4-row cultivator	1956	200	30
wagons (two)	1956	185	28
sprayer	1957	250	17
side rake	1954	75	25
6-foot combine	1953	600	189
4-row puller	1957	75	12
Elevator	1950	225	1

*Machinery was appraised by Glenn L. Archer, Auctioneer, Lansing, Michigan.

**Depreciation is computed on a straight line basis.

Buildings

Farm account records of the area were used in estimating a typical building inventory and the building valuations were those set by the farmers in their records.[1] Table III indicates the assumed building inventory, the year when the buildings were built, the size, the present value, and the assumed depreciation. The straight line depreciation was based on the values stated in Table III.

TABLE III

THE AGE, SIZE, DEPRECIATION AND VALUE OF THE INITIALLY OWNED BUILDINGS

Building	Year Built	Size	Value (dollars)	Depreciation* Per Year (dollars)
House	1937	3 bedroom	6,000	420
Barn	1928	32 x 60 x 40	4,000	280
Machine shed	1950	20 x 30 x 20	500	50
Garage	1946	14 x 22 x 9	500	50
Silo	1936	12 x 30	500	35
Corn crib	1947	5 x 30 x 10	500	35
Grainery	1948	20 x 24 x 10	1,000	70

*Depreciation is based on straight line method.

Labor

Family labor for this farm included the operator working full-time and his son working full-time during the summer and ten percent of the

[1]Consultation with people acquainted with the area. Farm Account Records, the records of specific farms of areas 7 and 8, Michigan State University, 1957 data.

time during the winter. An hour of the boy's labor and of the hired labor was valued at 90 percent of the operator's time.

Net Worth

Bankers were consulted as to the net worth of a typical farmer. The farm was valued at \$72,000 (160 acres at \$450 an acre) and the machinery was appraised at \$7,000. The initial debt of \$21,000 was assumed to be a real estate mortgage giving the farmer a net worth of \$58,000 and with this initial net worth as the collateral, the supply curve for credit was synthesized.

CHAPTER II

METHODOLOGY FOR ENDOGENOUS DETERMINATION OF OPTIMUM ASSET STRUCTURE

The methodological problem is to incorporate an economic definition of fixed assets into a linear programming formulation which can handle both capital expenditures and current disbursements. Capital expenditures and current expenditures must be converted to comparable units so that the most profitable investments can be determined.

Fixed Asset Definition

Assets cost more when purchased than can be received when sold because of taxes, transportation costs, transfer fees, profits of middlemen and commissions. For example, when a farmer sells a tractor for cash to a machinery dealer and later decides to repurchase it, the machinery dealer will typically charge enough above the price that he gave the farmer to cover his operating costs and make some profit. In this case, the difference between the cost of acquiring and the salvage value (amount received when sold) of the tractor is the machinery dealer's costs plus his profit.

The marginal value product is the additional amount that the last unit of asset adds to gross income. If the marginal value product (MVP) is greater than the acquisition cost (Pa), point A in Figure 1, it is profitable to purchase the asset till the MVP is equal to Pa. If the

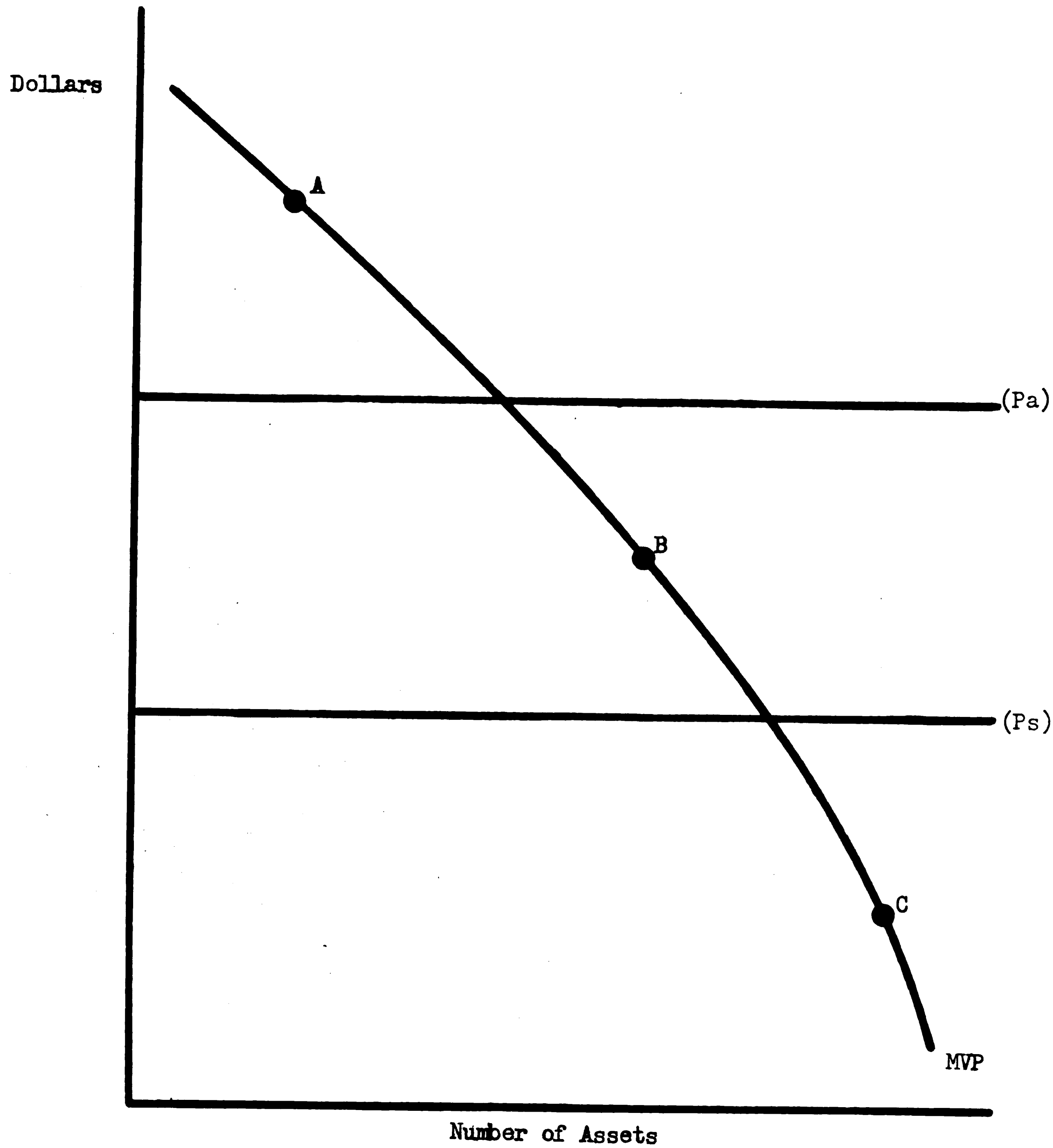

Figure 1. Fixed Assets.

MVP is less than the salvage price (Ps), point C in Figure 1, it is profitable to sell the asset till the MVP is equal to Ps. If Pa is equal to or greater than the MVP and the MVP is equal to or greater than Ps, point B in Figure 1, the level of the asset is fixed and it is not profitable to vary it.

Conversion of Stocks to Flows

A definition of a fixed asset has been explained and could be incorporated into a linear programming approach, but only for assets that last one year or less. In order to handle capital expenditures, the model must take into account the fact that some assets last longer than others.

Since capital expenditures are stocks (assets which produce services for more than one year) and flows are the services produced in one year, the problem is either to convert stocks to flows or flows to stocks so capital will be allocated to the most profitable use. Because one time period must be chosen for comparing all assets, and stocks may last indefinitely or only a few years, it was considered wiser to convert stocks to flows. Therefore, stocks were converted to services which an asset would produce in one year and all investments were made on the basis of one year's cost and one year's revenue.

Discrete Problem When Stocks are Converted to Flows

In the analysis where stocks are converted to flows, the purchasing of less than discrete units of capital expenditure becomes a major problem. One basic assumption made in linear programming is that all assets are perfectly divisible; however, most capital expenditures are not divisible even though current expenditures are.

When fixing an indivisible asset at some discrete level, the amount of gain or loss cannot be measured because: (1) the size of the steps in the marginal factor cost curve are unknown since only one point in the optimum solution is obtained, and (2) the marginal factor cost curve and the marginal value product curve shift due to different fixed factors and consequently changing ratios of inputs. The steps in the marginal factor cost curve in Figure 2 from C to B and from B to E are unknown because we get only point B from the optimum solution. It is necessary to know these distances between steps in order to determine the amount of gain or loss between different discrete units. Also, the ratio of inputs change (ratio of inputs being fixed to other inputs) when discrete levels are fixed; the MVP and MFC curves shift because the curves are now derived with a different ratio of inputs.

As more indivisible assets are fixed at the most profitable discrete levels, the ratios of the inputs keep changing due to the additional fixities. Because the ratios of the inputs keep changing, the levels of assets previously fixed may no longer be the most profitable.

The larger the difference between acquisition cost and salvage value, the more the ratios of inputs can change (with a corresponding change in the MVP and MFC) before a different discrete level is more

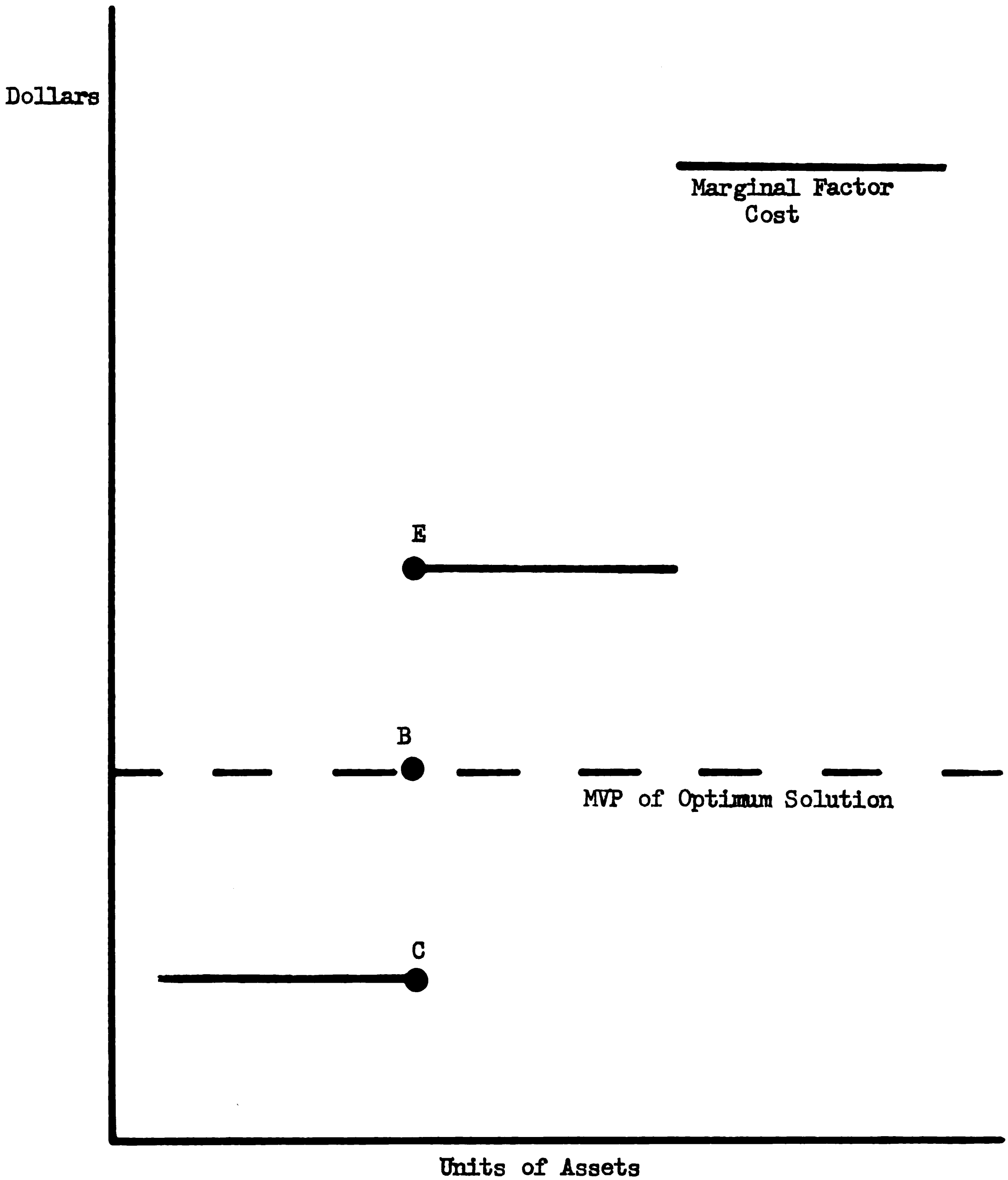

Figure 2. The Marginal Value Product and Marginal Factor Cost When Comparing Discrete Units.

profitable.[1] Therefore, the assets subject to the greatest fixity (largest difference between acquisition and salvage) were solved at discrete levels first.

Endogenous Determination of Asset Fixity

The flow costs of all assets for one year were considered to be: depreciation, taxes, interest and repairs. All of the costs of acquiring assets were subtracted from net profits in the various activities of the model. Depreciation and taxes were included in asset acquisition activities. Interest was subtracted from profits when money was borrowed through credit acquisition activities, while repairs were included as crop costs.

The price differential between acquisition cost and salvage value widens each time a higher interest rate is reached. As the rate of interest increases equally for both acquisition cost and salvage value, the acquisition cost increases by larger absolute amounts since it is always greater. At the point where credit reaches the absolute limit, the acquisition cost rises to positive infinity insuring fixity or sale of all assets. Since the acquisition cost is infinity, no more assets would be purchased and any asset would be sold if the MVP was less than salvage value. Therefore, all assets in the optimum were fixed with the acquisition cost being greater than or equal to the MVP and the

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[1]Providing the MVP's of all assets were the same relative distance from acquisition cost and salvage value.

latter being greater than or equal to salvage value. The above was the basic logic used for determining endogenously the levels of assets. For a more complete explanation of the model used in this analysis, refer to Appendix I.

CHAPTER III

DATA AND ALTERNATIVES

The purpose of this chapter is to present the data used, clarify the relationships assumed, and describe the possible alternatives. These are presented so a comparison can be made between what was possible and what was optimum.

Data

The relationships in the data assume recommended farm practices; some are currently adopted and others are not. Emphasis was placed on incorporating in the data new labor saving technologies, some of which will be presented as alternatives for comparison with current practices. The assumptions incorporated in the data are discussed below.

Field Time Available for Machinery and Labor

The time available on a cash crop farm for either labor or machinery is the time that can be spent in the field. Factors which determined the useful field time are: weather, necessary operational conditions, and timeliness.

Weather. The important considerations taken into account were: length of day, average daily cloudiness, rainfall during specific periods, frequency of rainfall, humidity, and temperature.[1]

Necessary Operational Conditions. Certain tillage and harvesting operations require more stringent conditions than others; navy bean harvesting requires drier conditions than corn harvesting. Each operation has been adjusted to take into account these conditions.

Timeliness. Each tillage and harvesting practice was divided into a period length during which the operation must be done if no damage was to occur to the crop. Certain tillage and harvesting operations were assigned shorter time periods than others; navy beans were harvested within a shorter period than wheat because rain will do more damage and is more likely during the navy bean harvest season. No comparison was made as to the cost of untimeliness in relation to the cost of the required capacity.

Field Time Available

To determine the field time available, it was necessary to ascertain the total number of hours when field conditions permitted the operator to perform tillage and harvesting operations. Larson presented the results of field time available studies for Georgia[2] and the periods of

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[1]Local Climatological Data, United States Department of Commerce, Weather Bureau, 1958.

[2]G. H. Larson, "Methods for Evaluating Important Factors Affecting Selection and Total Operating Costs of Farm Machinery," Unpublished Ph. D. Thesis, Michigan State University, 1958, p. 32.

time when selected tillage and harvesting operations would occur for the Lansing area.[1] These were adjusted for Saginaw Valley and Thumb Area conditions by conferences and studies of weather, necessary operational conditions and timeliness. Three professors[2] and three students acquainted with the area were asked when tillage and harvesting operations occurred and the period of time available for each operation. The adjusted field time available for the Saginaw Valley and Thumb Area was quantified and divided into nine periods as shown in Table IV.

TABLE IV

MACHINERY AND LABOR TIME AVAILABLE BY TIME PERIOD FOR TILLAGE AND HARVESTING OPERATIONS

Periods	Days in Period	Hours in Day	Machinery[a] Total Hours	Labor Total Hours[b]
April 15-May 10	9	12	110	120
May 10-30	9	12.5	110	150
June 1-15	7	13	90	180
June 15-30	8	13	100	200
July 1-30	18	13	230[c]	440
August 1-27	17	12	200	380
August 27-September 15	10	11	110[d]	140
September 15-30	6	10	60	70
October 1-November 15	16	9	140[e]	160

[a]Also the number of hours that hiring a man would add to the labor restriction.
[b]Includes one full-time man plus a boy in high school (boy add 90% of operator's time June, July and August and 10% during the rest of year).
[c]Time for combining wheat 30% lower than figures stated because foliage must be dry.
[d]Time for combining navy beans 50% lower than figures stated because foliage must be dry and damage from heavy rain could be great.
[e]Time available for picking corn 20% lower than figures stated because of wet fields.

[1]*Ibid*. p. 33.

[2]Dr. Clarence Hansen, Department of Agricultural Engineering; Dr. Lynn Robertson, Department of Soil Science; Dr. Carter M. Harrison, Department of Farm Crops; College of Agriculture, Michigan State University.

Each of these encompassed a time period during which tillage or harvesting operations were assumed to be accomplished.

Machinery Capacities

Two important considerations in determining equipment size are the field time available and the time required to perform the necessary tillage and harvesting operations in the production of a crop. The assumptions made with respect to machine capacities are given in Table V. The speed and time loss (due to turning and overlap) shown in Table V were used in calculating the acres a particular machine could cover in an hour.

Number of Tillage and Harvesting Practices

The use of minimum tillage was assumed in the study as recommended by the Departments of Soil Science and Agricultural Engineering of Michigan State University[1] and the number of tillage practices used were based on conferences with faculty of Michigan State University.[2] Table VI, presents a list of the assumed tillage and harvesting practices and the dates when they were performed.

Minimum Materials Handling

In order to improve the handling of materials, routes should be

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[1]Based upon conferences with members of each department and current publications.

[2]Dr. Lynn Robertson, Department of Soil Science; B. H. Grigsby, Department of Botany and Plant Pathology; and Boyd R. Churchill, Department of Farm Crops.

TABLE VI

TILLAGE AND HARVESTING OPERATIONS NECESSARY FOR SELECTED CROPS

	Corn	Corn With Pre-emergence	Wheat	Navy Bean	Navy Beans with Pre-emergence	Sugar Beets Hand Hoe With Pre-emergence	Sugar Beets Hand Hoe	Sugar Beets Thin	Sugar Beets Thin with Pre-emergence
April 15 - May 10						←plowing→			
						←planting→			
May 10-30	←plowing→								
	←planting→								
June 1-15	Cult.→			←plowing→			←Cult.		
				←planting→		←hand hoe→		←mechanically thin→	
June 15-30	Cultivate→					Cultivate→		mechanically thin	
July 1-30			Combine	←Cult.					
				←cultivate→					
August 27 - Sept. 15				←pull→					
				←rake→					
				←combine→					
Sept. 15-30			Disc→						
			Plant→						
Oct. 1 - Nov. 15	←pick or pick-shell→					Harvest→			

systematically analyzed and organized.[1] The following bottlenecks were located and by-passed in this study by assuming the use of improved materials handling procedures.

Bulk fertilizer was purchased and custom spread in the fall, since the spring season is busy with the plowing and planting of crops. It was cheaper to buy bulk fertilizer custom spread in the fall than it was to buy it in the sack or have it custom spread in the spring.[2] Fertilizer spread on the level land in this area is as effective when spread in the fall as when spread in the spring.[3]

The corn storage included as an alternative, was located so a minimum amount of hauling at harvest time was necessary since time is more valuable when crops are ready to harvest.

Analysis and systematic organization of materials handling may save considerable labor and improve the working conditions at a very low cost. As projected labor prices were relatively high, methods which conserved the use of labor were assumed.

Price Projections

If the relationships between the prices of important variables change, the optimum solution changes. An attempt was made to determine

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[1]"Plan Your Own Materials Handling System Now," Materials Handling, Successful Farming, Third Edition, pp. 15-19.

[2]It costs $6.00 per ton to have fertilizer bulk spread and $4.50 for sacking. Since a $2.50 discount exists for fall delivery, custom spread fertilizer in the fall cost $2.50 less per ton than spring custom spread and $1.00 less per ton than fertilizer in the sack in the spring.

[3]This statement was a product of consultation with Dr. Lynn Robertson, Department of Soil Science, Michigan State University.

if and how the relationships between prices were going to change in projecting prices five years in the future.[1]

Over the last ten years, crop prices have decreased, machinery prices increased, and labor prices increased; these trends were extended to estimate future prices. Corn, sugar beets, navy beans and wheat prices were investigated individually.[2] Corn prices were projected lower because of the surplus of feed grains, and navy bean prices were projected lower because of a trend towards lower consumption. Because of wheat surplus and the possibility of support prices dropping to the world's level of prices, wheat prices were also projected lower. Table VII shows the price projections for corn, wheat, navy beans and sugar beets.

TABLE VII

FIVE YEAR PRICE PROJECTIONS FOR CORN, WHEAT, NAVY BEANS, AND SUGAR BEETS

Crop	Average Price for Period 1947-1956	1956-1958	Project Prices for 1964
Corn	1.48 $/bushel	1.13 $/bushel	.90 $/bushel
Wheat	2.04 $/bushel	1.93 $/bushel	1.50 $/bushel
Navy Beans	7.75 $/cwt	6.60 $/cwt	5.90 $/cwt
Sugar Beets	12.25 $/ton	12.46 $/ton	11.25 $/ton

[1] J. T. Bonnen, American Agriculture in 1965: Testimony given before the Agricultural Policy Subcommittee of the Joint Economic Committee of the Congress of the United States, Agricultural Economics Department, Michigan State University, December 1957.

[2] John N. Ferris was consulted on estimating prices of the crops five years from now. He is author of The Outlook, Department of Agricultural Economics, Michigan State University.

All crop prices have decreased but machinery prices have increased between one and two percent per year over the last 10 years. This trend of machinery prices was extended with the result that projected prices of machinery, new and used, were 10 percent higher than present prices. The prices were predicted with the hope that the results of the study would apply a longer time in the future.

Alternatives

The data from the previous section were integrated into alternatives. Alternatives are specific machine sizes or operations (not combinations of machinery). Example: a 4 row cultivator. The following categories of alternatives are discussed: credit, labor, machinery, buildings, crops, fertilizer, and pre-emergence weed sprays.

Supply Curve for Credit

The different sources of credit considered were: private banks, the Federal Land Bank, a Production Credit Association (PCA), land owners as credit contractors, and machinery dealers. The credit position of the typical farmer and the possible alternatives were obtained from previous studies[1] and by interviewing bankers, machinery dealers, and professors[2] acquainted with the area. The amounts of credit and the

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[1]The most important previous study was Gerald I. Trant, "Institutional Credit and the Efficiency of Selected Dairy-Farms," Unpublished Ph. D. Thesis, Department of Agricultural Economics, Michigan State University, 1959.

[2]E. B. Hill and R. C. Hoglund, Department of Agricultural Economics, Michigan State University. Both were helpful in determining the supply curve for credit.

conditions under which a typical farmer could borrow are presented in Table VIII.

TABLE VIII

THE LOAN VALUE, YEARS TO REPAY, AMOUNT REQUIRED TO REPAY, INTEREST RATES AND AVAILABLE LIMITS OF VARIOUS LENDING AGENCIES*

Sources	Loan Value	Years to Repay	Annual Commitments Per Dollar Borrowed	Interest Rates (percent)	Limit (dollars)
General Sources*					
Mortgage on original land (Federal Land Bank and Insurance Companies)	.45	20	.0837	5.5	15,000
Chattels (Bank, PCA)	.45	3	.3776	6.5	5,500
Specialized Sources**					
6% land contract (credit from previous land owner)	.90	20	.0872	6	54,000
7% land contract (credit from previous owner)	.90	20	.0944	7	54,000
Machinery dealer	.50	3	.4251	13	20,000
Mortgage on purchased land (Federal Land Bank and Insurance Companies)	.45	20	.0837	5.5	36,000

*From the general sources, credit can be obtained without purchasing any assets.

**From the specialized sources, credit can be obtained only if the asset is purchased.

Lending agencies will lend a certain proportion of the value of the collateral (loan value). The annual commitments are the yearly payments for each dollar borrowed; these included interest and repayment of principle. The loan values and annual commitments are shown in Table VIII.

When borrowing money from machinery dealers, the interest rate is commonly stated as 6 percent per annum. However, interest is based upon the full value of the loan without discount for payments, so the interest charges usually exceeds 13 percent per annum simple interest.

Labor

Hiring Labor. It was assumed that labor could be acquired only in 6 months periods: from January 1st until June 30th, and from July 1st until December 31st. Each 6 month period included a slack period of about two months in which little but machinery repair could be done. Dependable, high quality labor is hard to acquire, so some security (hiring for at least 6 months) was assumed. Wages were projected five years, and \$300 a month was regarded as the price necessary to hire competent farm labor.

Selling Labor. The farm operator could sell his labor in periods of 6 months or longer at \$250 a month. Labor salvage was priced lower than labor acquisition, because of the expense of the operator's transportation to and from work, and the extra time and bother that would be required to obtain a job.

Machinery

The types of machinery alternatives included in this problem were the use of different sizes, custom hiring, and the use of machines that would do comparable jobs. Table IX shows all the machinery alternatives considered except for those machines which were in the initial farm situation. The new machinery costs (repairs, lubrication, depreciation, and taxes) were based upon the new projected prices. Used machinery was not considered because it would make the problem too complex.

Custom harvesting can substitute for ownership of the implements. The services commonly hired in this area were corn picking, picker-shelling, combining, and sugar beet harvesting. In a survey conducted by Hoglund in 1954[1] the following percentages of crops were custom harvested in this area: corn, 59 percent; navy beans, 22 percent; wheat, 3 percent; and sugar beets, 42 percent. Other custom machinery services were not commonly hired and therefore were not considered in this problem. An explanation of how custom harvesting was handled in the model is presented in Appendix I.

Buildings

Corn storage in 1000 bushel bins could be acquired if profitable. If the picker was used, metal wire cribs were required for ear corn and if the picker-sheller was used, metal bins were required for shelled

[1]C. R. Hoglund, unpublished data from survey, 1954.

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corn storage. The assumptions concerning storage and drying of ear and shelled corn are presented in Table X.

TABLE X

ALTERNATIVE STORAGE POSSIBILITIES FOR EAR AND SHELLED CORN

Buildings	Projected Price[a] for 1964 (dollars)	Building Life[c] (years)	Depreciation and Taxes (dollars)	Repairs as Percent of New Cost
Metal wire crib	550	20	29.5	7
Metal bins	484	25	20.6	7
Drier[b]	550	10	95	10

[a] Ten percent is added to current prices.
[b] Drier is considered part of the necessary set-up for cribs and bins.
[c] Building life, Depreciation and Repairs for all buildings were taken from J. M. Nielson, _op. cit_.

In this area, the moisture content of corn is too high to store for a year without loss by spoilage. With this in mind, storage could not be acquired without a drier. Ear corn was permitted to remain in the crib till spring when the moisture content was assumed to be 21 percent. It was then dried to 15 percent. Shelled corn was dried at harvest time from 40 percent to 15 percent. The return for drying and storage was 16 cents a bushel which was the current government payment for the storage of corn for a year.

Crops

Four crops were considered: corn, wheat, sugar beets, and navy beans. Restrictions were placed on the acreages of wheat, sugar beets, and navy beans. Wheat acreage was restricted to 12 percent of the tillable land because of acreage allotments while area acreage quotas restricted sugar beets to 15 percent of the tillable land. Navy bean acreage was restricted to 50 percent of the tillable land because of disease problems. The four crops could combine in any proportion as long as each crop was equal to or below its acreage restriction.

Fertilizer

Three levels of fertilizer application were considered, low, medium, and high. Economic research in cooperation with Tennessee Valley Authority has been designed to determine the total response curve as represented by the three levels.[1] The low level was equivalent to the recommended level given in Fertilizer Recommendations for Michigan Crops.[2] The fertilizer response given in Table XI were for Sims or Wisner soils (commonly called Brookston).

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[1]"A Progress Report of the Studies on the Economics of Fertilizer Use in Michigan," Conference for Cooperators in the TVA Agricultural Economic Research Activities, Tennessee Valley Authority, Division of Agricultural Relation, March 24-26, 1959.

[2]Fertilizer Recommendations for Michigan Crops, Extension Bulletin 159 (Revised), Cooperating Extension Service, Departments of Soil Science and Horticulture, Michigan State University, October 1957, p. 16.

TABLE XI

FERTILIZER APPLICATIONS: RESPONSE AND COST
FOR WISNER AND SIMS SOILS

Crop	Level in Study	Fertilizer Application N^a	$P_2O_5{}^b$	K_2O^c	Yield Response (per acre)	Fertilizer Cost Per Acre (dollars)
		- - - (pounds) - - - -				
Corn	low	100	50	50	70 bushels	21.50
Corn	medium	140	80	50	85 bushels	30.10
Corn	high	200	120	50	100 bushels	42.50
Wheat	low	30	50	20	38 bushels	10.20
Wheat	medium	40	80	40	43 bushels	15.60
Wheat	high	60	120	80	48 bushels	24.40
Sugar Beets	low	50	110	80	15 tons	22.00
Sugar Beets	medium	90	150	80	18 tons	31.60
Sugar Beets	high	140	200	100	21 tons	44.60
Navy Beans	low	20	40	20	26 bushels	7.80
Navy Beans	medium	45	60	20	32 bushels	13.30
Navy Beans	high	100	80	20	38 bushels	23.00

[a] Nitrogen was figured at a cost of .14 a pound.
[b] Phosphate was figured at a cost of .10 a pound.
[c] Potash was figured at a cost of .05 a pound.

Pre-emergence Weed Sprays

Pre-emergence weed sprays are usually more effective than post-emergence sprays. Many new and improved sprays are being tested by the Michigan State University Experiment Station and will soon be released for public usage. Table XII presents the assumptions made about pre-emergence sprays on the basis of a bulletin on weed control and

TABLE XII

PRE-EMERGENCE SPRAYS: APPLICATION RATES, COSTS INCURRED, CHEMICALS USED, AND TILLAGE SAVED

Crop	Chemicals	Application Rates in Pounds of Actual Chemicals	Cost Per Acre (dollars)	Tillage Saved From Spraying
Corn	2,4-D(ester)	2	3.00	1 cultivation
Navy beans	EPTC	2	8.00	1 cultivation
Sugar beets (mechanically thinned)	TCA and Endothal	5 lbs TCA and 4 lbs Endothal	14.00	1 cultivation
Sugar beets (hand hoed)	TCA and Endothal	5 lbs TCA and 4 lbs Endothal	14.00	7 hours hand hoeing

discussion with weed specialists.[1] The best spray to apply will depend on weather conditions and other variables not handled in problem.

Pre-emergence sprays were considered as substitutes for cultivations. In corn, sugar beets which were mechanically thinned, and navy beans, pre-emergence sprays were substituted for one cultivation. In sugar beets which were hand hoed, spraying substituted for 7 hours of hand hoeing.

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[1]B. Churchill and B. Grigsby, Weed Control in Field Crops, Extension folder F-222, Cooperative Extension Service, Michigan State University, March 1956, 6 pp.; also, personal consultation with B. Grigsby and B. Churchill.

CHAPTER IV

THE FINAL OPTIMUM AND THE COMPARISON MADE WHEN INDIVISIBLE ASSETS WERE SOLVED FOR AT DISCRETE LEVELS

This chapter presents the optimum solutions but the interpretation of these results are left to Chapter VI. The final optimum is first described in terms of what did happen and then in terms of what would happen if additional units of inputs were used.

Comparison of Solutions with Discrete Levels of Assets

For indivisible assets two problems, identical in all respects except for the discrete level of the asset, were solved and compared. The asset was fixed at the most profitable discrete level. To alleviate the problem of previously fixed assets no longer being the most profitable, the indivisible assets subject to the greatest fixity (largest difference between acquisition cost and salvage value) were solved at discrete levels first. The assets solved at discrete levels in this problem were, tractors, planters and cultivators. To secure a picture of what happens when assets were solved at discrete levels, a comparison was made between solutions.

First Solution

In the first solution, 161 acres of land were purchased. Multiples of forty acres were considered as discrete units for land. In the optimum solution, land purchase was only one acre in excess of four, forty acre units so it was assumed that the purchase of 160 acres was the most profitable. Therefore a tractor, the asset next most subject to fixity was solved at a discrete level in the next problem.

Second Solution

In the first solution .4 of a 3 to 4-plow tractor was purchased and a little over one 2-plow was salvaged. The initial inventory contained two 2-plow tractors and one 3 to 4-plow tractor. In this solution, one 2-plow was retained and the problem was re-run to compare the use of one 3 to 4-plow tractor with two 3 to 4-plow tractors; it was found that one was more profitable than two. Planters and cultivators were the assets next most subject to fixity.

Third and Final Solution

Four-row planters and 4-row cultivators were compared with 6-row planters and 6-row cultivators. All remaining assets were fixed by budgeting since computing time was limited; it was found that 6-row planters and cultivators were more profitable than 4-row planters and cultivators. The MVP's and all the comparisons were made with the

6-row equipment because this was the optimum solution with assets fixed at their most profitable discrete levels.

Comparison of Three Solutions

The assets were combined at the high profit point in the first optimum, assuming all assets to be completely divisible, therefore profits were lowered when assets were fixed at their appropriate discrete levels. The assumption that all assets are perfectly divisible causes unrealistically high profits, while asset indivisibility causes lower profits. These lower profits are closer to what farmers would obtain because they must buy indivisible assets. With all assets considered as variable, the amount above annual commitments (returns left after all costs and $3200 living expense are subtracted from profits) was $4,936 and labor income was $9,120.[1]

In comparing the next two optima, both of which have land fixed at 320 acres and one 2-plow tractor, the amount above annual commitments and labor income was $4,770 and $8,740 for one 3 to 4-plow tractor and $3,748 and $8,660 for two 3 to 4-plow tractors. The next two optima compared 4-row planters and cultivators with 6-row planters and cultivators with all remaining assets fixed. With one 4-row planter and one 4-row cultivator, the amount above annual commitments was $3,627 and labor income was $7,695 while with one 6-row planter and one 6-row

[1]Labor income does not include the wages the operator would receive from off-farm work from July 1st till the middle of March.

cultivator, the amount above annual commitments was $3,705 and labor income was $8,176.

General Results of the Optimum Solution

Before the investments in the optimum are studied, it is interesting to note how much credit and from what sources the credit was obtained. Table XIII presents the amount of credit used in the optimum solution and the maximum amount that could have been borrowed from each source. All investment adjustments were made with the available credit.

TABLE XIII

THE AMOUNT OF CREDIT USED FROM VARIOUS LENDING AGENCIES IN THE OPTIMUM SOLUTION[a]

Sources	Interest Rate (percent)	Limit (dollars)	Amount Used in Optimum (dollars)
General Sources[b]			
Mortgage on original land	5.5	15,000	15,000
Chattels (Banks, PCA)	6.5	5,500	5,500
Specialized Sources[c]			
Mortgage on purchased land	5.5	36,000	0
Land contract	6	54,000	54,000
Land contract	7	54,000	18,000
Machinery dealer credit	13	20,000	1,000

[a]For a more complete analysis of credit, reference is made to Table VIII.

[b]Credit obtained by mortgaging assets initially owned.

[c]Credit obtained only if the asset is purchased.

Of the specialized credit sources for land, all of the six percent and about one-third of the seven percent land contract was used. None of the five and one-half percent credit was used, which points out the importance of down payments. Land contracts have a down payment of 10 percent while the five and one-half percent mortgages had a down payment of 55 percent.

The operator of the farm sold his labor from July 1st to March 15th since he hired custom work for the harvesting of his crops. No additional labor was required to manage and operate the farm.

The machinery for the optimum solution consisted of: a 2-plow tractor, a 3 to 4-plow tractor, a 2-bottom 14 inch plow, a 3-bottom 14 inch plow, a 6-row planter, a 6-row cultivator, a bean puller, an 8-foot disc, a rake, a 4-row thinner, a 9-foot drill, and 2 wagons.

The machinery in the optimum solution differed from the initial solution in the following way: a 2-plow tractor, a 4-row planter, a 4-row cultivator and a 6-foot combine were sold; a 6-row planter a 6-row cultivator, and a sugar beet thinner were acquired. Picking was hired for corn, combining for wheat, navy beans, and harvesting for sugar beets.

The maximum acreages of sugar beets, navy beans, and wheat were grown; therefore, excess acreage was planted to corn. In the optimum solution, 136 acres of navy beans, 40 acres of sugar beets, 32 acres of wheat, and 63 acres of corn were raised.

Presented in the fertilizer alternatives in Table XI is the optimum fertilizer application level for corn, the medium level:

140 pounds of nitrogen, 80 pounds of P_2O_5 and 50 pounds of K_2O yielding 85 bushels per acre. Optimum wheat production was achieved at the medium fertilizer level: 40 pounds of nitrogen, 80 pounds of P_2O_5 and 40 pounds of K_2O which yielded 43 bushels per acre. For sugar beet production, the high fertilizer level was most profitable: 140 pounds of nitrogen, 200 pounds of P_2O_5 and 100 pounds of K_2O with a yield of 21 tons per acre. A navy bean yield of 38 bushels per acre maximized profit when fertilized at the high level: 100 pounds of nitrogen, 80 pounds of P_2O_5, and 20 pounds of K_2O. These results indicate that farmers should use additional amounts of fertilizer to maximize profits although it may be necessary to borrow money at 13 percent interest. The results also indicate that current fertilizer recommendations for crops are too low.

Although hand hoeing of sugar beets with the use of pre-emergence weed sprays was nearly as profitable as mechanical thinning and cultivating, present costs prohibit the wide usage of these sprays for sugar beets, and navy beans. However, the use of pre-emergence sprays on corn was highly profitable.

All corn was sold at harvest time because money necessary for corn crib construction had better alternative uses. Government payments were not large enough to cover all the costs of storage, which included drying and payment of interest.

The Marginal Value Products of Assets in the Optimum Solution

In programming, the marginal value product is the return an additional unit of asset would add to net profit. The marginal value products are presented in Table XIV to illustrate what an additional unit of asset would have been worth. The following discussion is an explanation of the marginal value product's of labor, machinery, credit, and crops as shown in Table XIV.

TABLE XIV

THE MARGINAL VALUE PRODUCTS OF ASSETS FIXED AT THEIR MOST PROFITABLE DISCRETE LEVELS

Equations	Limiting Period	MVP's (dollars)	Units
Labor	June 1-15	22.59	hour
Labor	September 1-15	3.01	hour
Labor	September 15-30	6.15	hour
Labor	October 1-November 15	5.27	hour
2-plow tractor service	June 1-15	14.87	hour
3-plow tractor service	June 1-15	31.65	hour
Cultivator service	July 1-30	.33	hour
Thinner	June 1-15	1.10	hour
Wheat combining	July 1-30	2.50	acre
Navy bean combining	September 1-15	3.91	acre
Picker-sheller service	October 1-November 15	4.23	acre
Wheat acreage restriction		10.52	acre
Navy bean acreage restriction		11.13	acre
Sugar beet acreage restriction		41.0	acre
Land		22.38	acre
Cash		.13	dollar
5.5 land mortgage		.075	dollar
6.5 chattel mortgage		.065	dollar

The high marginal productivity of labor from June 1-15 (period in which land for 136 acres of navy beans must be plowed and planted) is partly due to the way labor was formulated in the problem since labor could be purchased only in six month periods. In order to hire labor for the period of June 1-15, (the most limiting period) labor had to be hired from January 1st to July 1st.

June 1-15 was the limiting period for tractor services for this farm firm. Although this period was limiting, the marginal value product was not large enough so that an additional tractor would be profitable.

Some, but not all, machinery dealer credit at 13 percent was borrowed in the optimum solution. If all machinery dealer credit had been borrowed, money would have been worth more than 13 percent; if no machinery dealer credit had been borrowed, money would have been worth less than 13 percent. Since some 13 percent capital was borrowed, but not all, the last dollar of credit used was exactly worth the interest charge. The MVP's of credit in Table XIV show the amount of gain in net profits which would occur when borrowing additional capital from the specified sources.

The marginal value products of an additional acre of a specified crop, limited by crop acreage restrictions, (not additional land but additional acres of crops within the 320 acres) are presented in Table XIV. For example, the sugar beets restriction has a value of $41 an acre which means that net profits would be increased $41 if an additional acre of sugar beets could be grown rather than the acre of corn which was grown.

CHAPTER V

LIMITATIONS

Many decisions were made which directly affected the optimum. These decisions or limitations (data, alternatives, methodology and pricing) are presented because they influence the interpretation of results.

Data

The final solution was optimum for the relationships in the data. Thus data which is not representative of actual possibilities would lead to false conclusions. The fact that data is based on recommended relationships, is reflected in the interpretation by an optimum which is attainable only if these relationships are accepted. In order to make the labor income which was made in the optimum solution, farm operators would have to adopt those recommended practices outlined in Chapter III.

Alternatives

The optimum solution represents the best combination of alternatives formulated. Although a large number of alternatives were formulated in the matrix, (85 equation and 300 activities) many

formulations were omitted because it was necessary to limit the problem to a workable size and consider only the most important variables. In analyzing the optimum solution only the formulated alternatives can be compared thus, one important source of income, livestock was not considered, so it can not be concluded from this study that livestock production would or would not be a profitable use of capital.

Methodological Limitations

In the problem, all assets could be purchased and all initial assets could be salvaged, but some assets may be absolutely fixed for certain operators. Thus, land may be impossible to purchase because none is available at reasonable prices. Also, the profitability of one asset may depend upon the acquisition of another asset. For example, certain advised investments in machinery would not be profitable unless the 160 acres of land was acquired. Individual cases in which assets are fixed at the initial levels were not handled in this model.

Another problem occurs because indivisible capital expenditures were allowed to vary in this model. To attenuate inherent errors which arise by assuming perfect divisibility, assets subject to the greatest fixity were solved in terms of discrete units. This manner of handling the indivisible problem was not completely satisfactory because of additional computations and chances of error. Two additional computations were necessary for each asset solved at a discrete level thus, it is evident that excessive computing time would result if all capital expenditures were solved at discrete levels. The chance for error occurs because previously fixed assets may shift to unprofitable levels as more assets are fixed. Since the assets most subject to fixity were solved first, this would minimize the possibility of assets shifting to unprofitable levels. The assets with the largest difference between acquisition and salvage values may be very close to an unprofitable level when fixed and shift to an unprofitable level as other assets are fixed.

Pricing Limitations

When using linear programming, the prices are assumed to be known with certainty. It is obvious that extending current trends does not result in price projections which are known with certainty, and if the relationships between prices change, the solution which would be optimum changes.

If the practices recommended in this thesis as being profitable were adopted by a large group of farmers, the price relationships would change and consequently different practices would be more profitable. These macro changes were not analyzed.

Another macro consideration, future uncertainty, should have been incorporated in the cost of acquiring assets but was not. If all revenues were discounted the same percentage for uncertainty, the relationships between the investments would not change but fewer investments would be made. Moreover, certain assets should have their revenues discounted relatively more than others. Assuming other factors equal, the assets that last longer should be discounted more because of greater risk and uncertainty. By not discounting capital expenditures, a comparative advantage was gained, and money was invested in them when it should have been invested in other assets with less uncertainty.

Personal Preferences

It was assumed in this analysis that maximization of profit is the only goal, but often this is not true. If more satisfaction could be gained by owning an extra 3 to 4-plow tractor, (when comparing discrete levels in Chapter IV, one 3 to 4-plow tractor was $90 more profitable than two 3 to 4-plow tractors) the tractor should be acquired. Often personal satisfactions gained from ownership of machinery outweigh economic losses incurred as a result. A comparison was made between custom harvesting and ownership of various necessary machines; it was assumed that custom work was available at harvest time and no charges were made for labor.

Net profits would decrease approximately $370 if a 2-row picker was acquired, and approximately $490 if a 10-foot combine was acquired instead of custom hiring. In comparing the initially owned 6-foot combine and custom hiring, $100 more profit would be made by keeping the 6-foot combine. All of the custom rates used in the study were those commonly charged in the area.[1] The charges for the combines and corn pickers

[1] Rates for Custom Work, Extension Folder F-161 (Revised), Michigan State University, 1957-58.

include depreciation, repairs, taxes and interest. Interest was charged at a rate of 13 percent because the cheaper rates of interest were previously used for alternative investments which returned more than 13 percent.

If the operator could acquire a job during this harvest period, the costs of owning machinery would be much greater than those stated above. Even with the greater costs involved, farmers may prefer to own their own equipment on small farms even though the acreage many times is not large enough to justify the acquiring of certain machines. The large number of harvesting machines owned by people with small acreages points out the importance of personal preferences.

CHAPTER VI

INTERPRETATION OF RESULTS

In order to obtain a bench mark, the optimum solution was compared with the average of the top one-third of the farmers in the area who kept Michigan State Farm Account Records.[1] It is realized that this is not a random sample of farmers in the Saginaw Valley and Thumb area but it should give some indication as to what farmers are doing presently.

The Comparison of Optimum with the Top One-Third of the Farmers Keeping Farm Account Records

In the farm account studies, certain criteria, gross income per $100 investment, returns to family labor and capital, labor income, and other guides are used in determining how efficiently farms are organized and operated. Usually, individual farms are compared with the other farmers keeping records so conclusions can be drawn as to how these farmers could increase earnings. In this study, a comparison between the upper one-third of farmers keeping records and the optimum was made and is presented in Table XV.

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[1]The discussion which follows always refers to the top one-third keeping farm account records, Farming Today, Area 8 Report, op. cit.

	1.4	5.0
Fertilizer per tillable acre	11.8	30
Investments		
Total	63,968	173,700

Attention is called to some of the organizational and operational changes these farmers should make if they want to increase earnings. The acreage of these farmers was close to 100 acres smaller than that suggested by the optimum. The additional land was probably responsible for other changes made in organization. Thus, larger equipment may now be profitable because the greater initial cost would be spread over more acres.

Forty-eight percent less labor per acre was used in the optimum in comparison with the top one-third farmers keeping records. The low amount of labor expended per acre can be explained by the absence of livestock production in the optimum and by the efficient labor organization assumed.

Crop expenses were greater per tillable acre in the optimum while gross income was also greater. This would suggest that additional profits were made not by reducing expenses but by increasing gross income by additional expenses such as fertilization, additional land, and larger equipment.

Fertilizer applications were over twice as great in the optimum as farmers are presently using. This would suggest that farmers are applying less than half the amount of fertilizer that they should be for maximum profits.

Present total investments are only about a third of that suggested by the optimum.[1] The cautious conservative attitudes of the farmers

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[1]Investments were based on book values in the farm account studies but on present predicted values in the optimum. Actual discrepancy in investments would be smaller than stated.

may be responsible for smaller investments than are profitable.

Labor income for the optimum was almost $2,000 greater than what farmers are presently earning. This labor income in the optimum, did not include the off-farm job possible from July 1-March 15.

In the farm account studies, farms are ordered from top to bottom in each of the individual efficiency measurements of organization and operation in Table XV. At least one farm in the area compares favorably in one efficiency measurement with the optimum, but none compared favorably in all respects. This suggests that individual farms are efficient in one or two respects but not in all respects.

Interpretation of Optimum

Crop Rotations

The crop acreage restrictions definitely influences the final rotation as the maximum acreages of sugar beets, navy beans and wheat were raised and the MVP's indicated that additional acreage of sugar beets would have been especially profitable. Although, corn was the least profitable crop, it was included in the optimum because all of the allowable acres of sugar beets, navy beans, and wheat were being raised. The results of this study can not be interpreted as suggesting corn acreage should be increased in the area.

Land Acquisition

Land was probably acquired because specialized credit sources for land had lower rates of interest than those for other investments

and more acres of high value crops could be produced. Land could be acquired through land contracting at seven percent interest while thirteen percent interest was being charged for other investments. Land contracting credit was not available for other investments because it could be borrowed only when land was purchased.

Larger Equipment

With increased acreage and increased labor costs, larger equipment (6-row planters and cultivators) were more profitable than initial equipment. Labor prices were projected higher than present prices, which also would have an influence towards making larger equipment more profitable. Since labor was formulated so it could be acquired only in periods of six months, a definite premium was placed on labor in the limiting periods tending to make larger equipment more profitable. June 1-15 was the limiting labor period in the spring since it was the time when 136 acres of navy beans had to be plowed and planted. With a premium on labor at this time it can be understood why the 3 to 4-plow tractor, which would pull a larger plow was more profitable; coupled with the cultivating of sugar beets during this period, it can also be understood why 6-row planters and cultivators were more profitable than 4-row. The greatest factor influencing the model towards small equipment was the high cost of capital.

Custom Hiring

The high costs of labor and the high costs of capital contributed to making custom hiring more profitable than owning harvesting machinery. Interest was thirteen percent and labor was limiting in the fall months during harvest season. This however ignores the problem of timeliness and convenience when using custom machinery.

Labor Income

Minimum materials handling, minimum tillage, and a wide choice of alternatives contributed to the high labor income. Labor income was lowered by projected increases in machinery and labor price, and by projected decreases in crop prices. However, these influences were outweighed by the efficient operations assumed and the increased acreage.

Conclusions

Individual farm situations vary and these conclusions will not apply with equal validity to all farms. However, some generalizations to maximize profit can be made on the basis of this study.

Adjustments in Farming

(1) Larger equipment, tractors, plows, cultivators, and planters should be used to minimize the labor requirements, provided it is possible to buy additional land.

(2) Additional farm acreage will improve total net earnings even after interest and other costs of owning land are paid.

(3) Use of more credit will increase earnings as credit can be profitable borrowed to make efficient farm adjustments.

(4) Heavier applications of fertilizer than are commonly recommended appear to be profitable. Indications are that fertilizer applications should be at least twice the amount being presently used by farmers.

(5) Coupled with heavy fertilization rates, intensive cropping should be practiced on this type of land. Judging from the results, sugar beet acreage should be increased because it was the most profitable crop produced. Navy bean acreage should also be increased as a second alternative crop.

(6) Pre-emergence sprays were practical to use on corn to control weed and minimize cultivation. These weed sprays would be profitable to use on sugar beets if hand hoed, but more profit could be gained by mechanical thinning with no pre-emergence weed sprays.

Methodological Conclusions

(1) Capital expenditures do not have to be fixed at initial levels, since the most profitable levels can be endogenously determined.

(2) The indivisibility of capital expenditures can be partially handled by solving for the assets which are most subject to fixity at discrete levels.

(3) Capital expenditures can be compared with current expenditures by converting them from stocks to flows. With this conversion, all assets can be compared and an over-all picture of the farm business can be gained with capital allocated to its most profitable use.

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APPENDIX I

APPENDIX I

LINEAR PROGRAMMING MODEL

The model formulated in this thesis, in general, follows the usual mathematical assumptions of the linear programming resource allocation problem. However, the asset structure of the farm was not assumed fixed, since the model provided for an increase or decrease in the amount of any of the physical assets considered in the firm.

In order to get a clear picture of the model, the whole matrix should be shown; however, the size and complexity of the matrix does not permit this. Instead the equations are listed and significant segments of the matrix are presented.

Equations

The following equations were used in the model. In order to facilitate reading, the equations representing different time periods for the same item are grouped in Table XVI.

Labor

Labor was divided into nine field time available periods. Months were not used as time periods because they did not coincide with machine operations. Time periods may encompass more than one machine operation but each operation had to be completed within its allowed time period.

Labor was measured in terms of hours available for field work. The labor hours available were assumed to be the same as the machinery hours available, since repairs, except breakdowns in the field, were to be accomplished during slack periods.

Machinery

By examining Table XVI, it can be seen that each time period for every different machine considered was an equation. Time periods were considered as separate restrictions to insure that time was available when needed. If the time periods were aggregated, time may exist for the machine but not when needed for one of the operations.

All machinery equations were stated in terms of field time available because this is the only time during which operations could be accomplished. An example of a machinery restriction and how it was handled is shown in Table XVIII.

Crop Restrictions and Credit

Crop restrictions were defined in terms of acres available, while credit was defined in one hundred dollar units. The manner in which credit and crop restrictions were handled is explained in a latter portion of this Appendix where segments of the matrix are shown and explained.

6-row Cultivator

6-row Cultivator		
46	June 1-15	0
47	June 15-30	0
48	July 1-30	0
4-row Thinner		
49	June 1-15	0
50	June 15-30	
6-foot Combine wheat		
51	July 1-30	
10-foot Combine wheat		
52	July 1-30	0
Puller (navy beans)		
53	August 27-S	110
Rake (navy be		
54	Augus	

ber 1-November 15	0
n storage	0
orn storage	

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d

ked

w

r

Activities

Crop

The majority of the variables in this model (228) were crop activities. Activities were defined as one crop, not a rotation. Table XVII lists all the crop activities which were formulated in the problem. In order to minimize repetition, two sizes of tractors and three levels of fertilizer are not shown. Each activity represents six crop activities in the model (1 x 2 tractor sizes x 3 levels of fertilizer).

TABLE XVII

CROP ACTIVITIES IN MODEL

Corn	Wheat	Sugar Beets	Navy Beans
437	c	4t7	4c7
43	cc	4t	4c
637		4h7	4cc7
63		4h	4cc
457		6t7	6c7
45		6t	6c
657		6ht	6cc7
65		6h	6cc
137		1t7	1c7
13		1t	1c
157		1h7	1cc7
15		1h	1cc

Key:

4	4-row planter and 4-row cultivator	t	mechanically thin
3	pick corn	h	hand hoe
5	picker-sheller	1	1-row planter hooked directly to plow
7	pre-emergence weed spray		
c	6-foot combine	6	6-row planter and 6-row cultivator
cc	10-foot combine		

Corn

The combinations considered for corn production were: 2,4 and 6-row cultivators; 4 and 6-row planters; plow plant; pre-emergence weed sprays; picker and picker-sheller; custom harvest; three levels of fertilizer; and 2 and 3 to 4-bottom tractors.[1] Any of the above combinations could have been in the optimum.

Wheat

Since wheat acreage was limited to 12 percent of the tillable acres, machinery selection was not considered as important for wheat as for other crops and different machine sizes were considered only for combining. A 8-foot disc and 9-foot drill were used in the production of wheat. Besides the two tractor sizes and the three levels of fertilizer, 6-foot and 10-foot combines and custom harvesting were combinations considered in the problem.

Sugar Beets

Since sugar beet acreage was limited to 15 percent of the tillable acres, it was unlikely that enough acres would be raised to justify a sugar beet harvestor, so all sugar beet harvesting was custom hired. Most of the sugar beets in Michigan are hand hoed and hand labor was

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[1]Throughout this discussion it was assumed that when a 2-plow tractor was used a 2-14 plow was used and when a 3 to 4-plow tractor was used a 3-14 plow was used.

available at $1.00 an hour. Hand hoeing; mechanical thinning; pre-emergence weed sprays; plow plant; 2, 4, and 6-row cultivators; 4 and 6-row planters; 2 and 3 to 4-bottom tractors; and three levels of fertilizer were possible combinations in the optimum.

Navy Beans

A rake and 4-row puller was used on all navy bean acreage. The activities contained the same alternatives as corn except 6 and 10-foot combines replaced the picker and picker-sheller.

Machinery

Since the model did not assume the asset structure of the firm was fixed, activities were provided for the purchase and sale of all machinery considered. Salvage activities were included for 2-plow and 3 to 4-plow tractors, 2-14 plow, 3-14 plow, 2-row cultivator, 4-row planter, 4-row cultivator, 6-foot combine, 8-foot disc, 9-foot drill, rake, puller, and wagon. Acquisition activities provided for the purchase of all the assets (stated above) which had salvage activities and in addition to a 1-row planter with hitch for a plow (plow plant), 6-row planter, 6-row cultivator, 4-row thinner, and 10-foot combine.

Segments of Matrix Presented

Investment Model

Essential to the investment model was the conversion of capital expenditures from stocks to flows. Stocks are assets which produce services for more than one year and flows are the services produced in one year. The conversion from stocks to flows was necessary so comparisons could be made with current expenditures. Therefore, both capital expenditures and current expenditures were compared on the basis of one year's services and one year's costs.

One year's cost of owning any asset consisted of depreciation, interest, repairs, and taxes. The value of a year's service was dependent on how limiting the asset was. Additional units of the asset were purchased when the value of a year's services exceeded the cost, but when the cost exceeded the value, units of the asset were sold.

To show how the model was formulated to include the costs for one year, the investment segment of the model is presented. All of the credit acquisition and salvage activities are included in Table XVIII. To simplify the table, a machinery activity representative of all machines was included since they are similar and affect the same equations. A crop activity representative of all crop processes was also included because they also are similar and affect the same equations.

Machin[illegible] Deal[illegible]	Land Mortgage Repayment	Salvage of Cash
i[illegible]	$-i$	$-i$
-100 $-(i+C_R)$	100 [illegible]$+C_r)$ [illegible]00	
100[illegible]		
100		

Salvage Assets			Acquisition Credit		
Machinery	Land	Land Contract	Mortgage on Initial Land	Land Mortgage	Banks PCA
$-DT$	$-T$	i	i	i	i
+					
	+				
$-V_s+1/2D$	$-(V_s-MR)$	-100	-100	-100	-100
DT	T	$-(i+C_R)$	$-(i+C_R)$	$-(i+C_R)$	$-(i+C_R)$
$-V_s+1/2D$	$-(V_s-MR)$		-100		-100
	(MR)		-100	-100	
	$(.45V_s-MR)$		1[illegible]		
$1/2\ V_s$					100

TABLE XVIII

BASIC INVESTMENT MODEL USED IN PROBLEM

	Crops	Machinery	Acquisition of Land Through Land Contract
Net profit equation	- Net pft.	DT[1]	T
Machinery	+	-	
Land	+		-
Money equation			
Cash	Cost	P-1/2D	P
Annual commitme	Net pft.	-DT	-T
Down payment	Cost	D_p	.1P
Land mortgage ou			
Sources of credit			
Mortgage on origin			
Mortgage on purchas			
Land contract			
Banks, PCA (Chattels,			
Machinery dealers			
Cr Source Restrict			
(CS age on newly			
(CSR tract			(.9p)
(CSR) dealer			

Abbreviati n ta

D = n

D_p = do

C_R = cap

MR = mort

V_s = salvag

i = interes

T = taxes

P = price

[1]Plus sign understood wh nventional li programming it means to

[2]Credit source restrictions the borrowing from sources which require ey can be bo

Investment Equations Presented in Table XVIII

Credit

Credit equations were divided into sources of credit and credit source restrictions. In Table XVIII the sources of credit were those equations which set absolute limits on credit from the sources considered. Credit source restrictions were designed to prevent money borrowing from certain sources until assets were purchased, since machinery dealers or land contractors would loan money only on assets purchased from them. However, these equations do not force the use of credit once the assets were purchased.

Money Equations

Cash Equation. This was a key equation, as all money except profits was funneled through it. The cash equation served the purpose of making sure that money was available and interest was charged on all investments. To facilitate this, the full price of investments and the amount borrowed flowed through this equation.

To determine this initial restriction, one-half the depreciation of all assets was added to the beginning restriction because depreciation occurs throughout the year, so the average amount present at any one time would be one-half the total amount. Since one-half was available at any one time, it could be spent and should be added to the initial cash equation. This idea also affects coefficients when

assets are purchased or salvaged because one-half the depreciation could be spent this year and was added to the coefficients when assets were purchased and subtracted when assets were sold.

Down Payment. This equation was included so investments would not be made unless money for down payment was available. Since differentiation between sources which require various down payment percentages must be made, each credit source would have required an additional activity for each investment if this equation had not been included. This equation then permitted differentiation between credit sources in the amount of down payment which they required.

Annual Commitment. As investments can not be made unless payments of interest and principle can be made, this equation functions to make certain that all yearly payments and costs were less than profits. All coefficients in the annual commitments equation were identical with those in the profit equation with the exception of credit acquisition activities. These coefficients differ in the credit acquisition activities, because a portion of the principle must be paid each year, which is an annual commitment but not a cost. The yearly annual commitments for borrowed money were presented in Table VIII.

Net Profit

Profits as measured by this equation were maximized in this problem. Anything which adds gross income increases this equation and all activities which incur costs decrease this equation.

Investment Activities Presented in Table XVIII

Asset Acquisition Activities

These activities provided for the purchase of all assets considered in the problem. The coefficients of these processes were price minus one-half depreciation in the cash equation and depreciation plus taxes in the annual commitments equation. Since down payment was required for asset purchase, asset acquisition activities decreased the down payment equation. Since additional funds could be borrowed from the machinery dealer, the machinery dealer credit source restriction was increased by the balance.

Asset Salvage

When an asset was salvaged, all annual commitments were added to net profit. Since chattel credit maximums were considered to be one-half the initial collateral, the chattel maximums were reduced by one-half the salvage value when assets were sold.

Credit Acquisition Activities

These processes provided for the borrowing of funds from various sources and decreased net profit by the interest paid. These activities were used to transfer money from borrowable funds to the cash equation where the money could be used for productive purposes.

Land Mortgage Repayment

The original mortgage of $21,000 had to be repaid if the firm went out of business or if more profitable uses of money could be found. This activity allowed for the initial debt to be repaid from other sources of capital.

Salvage of Cash

Because money has alternative uses, it was assumed that four percent interest would be paid for any available money not being used by the firm. If investments in the firm made less than four percent, the initial cash on hand would be salvaged.

Crop Acreage Restrictions

Since the crops were formulated as separate activities, the entire farm could be planted to one crop unless restrictions were placed on acreage. In this problem, wheat and sugar beets were limited by government acreage allotments and area quotas respectively, while disease problems restricted navy bean acreage. These restrictions were formulated so conditions faced by farm firms were approximated.

Since land could be acquired and sold and because these restrictions are somewhat proportional to the total acreage, these restrictions increased and decreased as land acreage increased or decreased as can be seen by analyzing Table XIX. Each of the crop activities shown in Table XIX represents all the processes for one crop.

TABLE XIX

FORMULATION OF INSTITUTIONAL RESTRICTIONS ON CROP ACREAGE
(Tillable Acres)

	Initial Level	Wheat	Navy Beans	Corn	Sugar Beets	Land Acquisition	Land Salvage	Equation Number
Government restriction on wheat	16	+10[a]	0	0	0	-1.2	+1.2	1
Wheat after navy beans	0	+10	-10	0	0	0	0	2
Navy beans	68	0	+10	0	0	-5.0	+5.0	3
Sugar beets after corn	0	0	0	-10	+10	0	0	4
Sugar beets	20	0	0	0	+10	-1.5	+1.5	5
Tillable land	136	+10	+10	+10	+10	-10	+10	6

[a]The signs follow conventional linear programming where - add to and + uses some of the initial restriction.

The wheat acreage was restricted in the following manner, government allotment $\geq$ wheat acreage $\leq$ navy bean acreage. Equation 1 in Table XIX prevents the wheat acreage from exceeding the government allotment. To prevent wheat from winter killing it must be planted early in the fall; navy beans were the only crop considered which were harvested early enough in the fall to be planted to wheat. The wheat after navy bean equation in Table XIX made certain that wheat could not be grown unless a comparable acreage of navy beans was grown. As the initial restriction was zero, no wheat could be grown until a navy bean crop was raised.

Sugar beet acreage was restricted to the following, sugar beet quota $\geq$ sugar beet acreage $\leq$ corn acreage. Because crop sequence is important in the fertilizer response, sugar beets were forced to follow corn. With the initial restriction of equation 4 in Table XIX zero, and corn adding to this restriction and sugar beets subtracting; sugar beets could not be grown unless corn was raised.

Comparison of Custom Harvesting with Ownership

If formulated with one crop activity for ownership and one for custom hiring, the number of activities would have been doubled for each crop harvested. However, in this formulation, the number of activities were not doubled but instead one process was added for each crop harvested. Since wheat, corn, and navy beans could all be custom harvested and harvested by the operator, this formulation saved 2397 (300 present activities x 2 custom harvesting of corn x 2 custom harvesting of wheat x 2 custom harvesting of navy beans - 3 added by this formulation) activities.

The problem was formulated so that all crop activities included, labor, tractor services, variable costs, and harvesting services as if the harvester was owned. It is obvious that if the harvesting was custom hired the above items would be saved. Therefore, the custom harvesting activity had coefficients which added the labor, tractor services, variable costs, and harvesting services to the appropriate equations. The custom hiring process also had a coefficient in the net profit equation which represented the costs of custom hiring.